Re-evaluation of the Netherlands' long-term climate targets

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Abbreviations

AER	General Energy Council (Algemene Energieraad)
CC	Climate Change
CDM	Clean Development Mechanism
CEE	Central and Eastern Europe
CFC	Chlorofluorocarbon
CHP	Combined Heat and Power
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eq.	CO_2 equivalent
COP	Conference of Parties
CDF	Cumulative Density Function
CPB	Central Plan Bureau (Centraal Planbureau)
CWB21	Commission Water Management 21st century (Commissie Waterbeheer 21e eeuw)
DALY	Disability Adjusted Life Years
DC	Developing Country
ET	Emissions Trading
EU	European Union
FCCC	Framework Convention on Climate Change
FM	Flexibility Mechanisms
GCM	General Circulation Model
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GNP	Gross National Product
HOT	Helping Operationalise article Two
HFC	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KM	Kyoto Mechanism
KNMI	Royal Netherlands Meteorological Institute (Koninklijk Nederlands Meteorologisch Instituut)

KP	Kyoto Protocol
KPFCCC	Kyoto Protocol to the FCCC
MS	Member States
N_2O	Nitrous oxide
NGO	Non-Governmental Organisation
PDF	Probability Density Function
PFC	Perflourocarbons
PIA	Participatory Integrated Assessment
PKB	Planologische Kernbeslissing
ppmv	parts per million (volumetric ratio)
PV	photo-voltaic
R&D	Research and Development
RIKZ	National Institute for Coastal and Marine Management (Rijksinstituut voor Kust en Zee)
RIVM	National Institute of Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu)
RIZA	Institute for Inland Water Management and Waste Water Treatment
RWS	Rijkswaterstaat (Netherlands)
SF_6	Sulfur hexafluoride
SRES	The IPCC Special Report on Emission Scenario's
TAR	IPCC Third Assesment Report
TCI	Tourism Comfort Index
THC	Thermohaline Circulation
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
VROM	Netherlands Ministry of Housing, Spatial Planning and the Environment (Ministerie voor Volkshuisvesting, Ruimtelijke Ordening en Milieu-beheer)
WG	Working Group
WUR	Wageningen University and Research Centre
WWF	World Wide Fund for Nature

Preface

It is intriguing to observe how in the last 15 years the problem of climate change has forced itself onto the scientific, political and societal agenda. Taking into account the nature, complexity and global scale of the problem, it is remarkable the rate at which a national and international scientific infrastructure (with the Inter governmental Panel on Climate Change (IPCC) as its main body) has taken shape. This development is of great importance, as governments and other actors benefit from reliable and authoritative scientific data.

Politicians have become rapidly aware of the significance of the problem. The Parliament in the Netherlands ratified the 1992 United Nations Framework Convention on Climate Change without any debate. Three years after ratification, the House of Representatives decided to conduct its own investigation on the subject, in order to better understand the nature of the problem and to be able to develop proposals for climate policies. From this moment on there was consensus in the Netherlands' political arena on the nature and importance of this environmental issue.

Society also showed a rapidly growing interest in the subject. Industry acknowledged that dealing with the problem of climate change posed both a burden and a challenge. Environmentalists turned the problem into one of their most important issues. Public awareness became slowly but steadily familiar with this environmental threat, for example through the relationship that was shown between extreme weather events and climate change. These developments have led to the formation of a diverse group of people that have great knowledge on the climate problem. For this reason, it is now possible to make use of this knowledge through a participatory integrated assessment (PIA), in order to formulate long-term targets for climate policy. This report benefits from the results of these developments.

Herein lies the great importance of this type of scientific work. First of all it draws the attention of policy makers to the necessity of, and the different strategies for, addressing this problem. Second, the ecological responsibilities of key stakeholders are highlighted by the presentation of the most recent scientific insights. It is then possible to get a better grasp of the problem in terms of knowledge, environmental ethics, political objectives and costs. Furthermore, this methodology establishes a pool of knowledge and insights with regard to the long-term nature of the problem, which can consequently be used repeatedly for short-term political purposes. This can only be successful, however, if science remains transparent and acknowledges the need for clear communication to politicians and other stakeholders. An appropriate method is to involve the responsible actors in increasing scientific insights and the formulation of sound policy responses.

In this way, it is possible to better understand each other's language and to stimulate one's own responsibilities.

This report shows that the formulation and articulation of long-term climate change control targets is still very much like finding one's way through thick fog. Much is still unclear and the risk of taking the wrong turn is ever present.

The Netherlands have a strong interest in following the right course to climate change stabilisation, simply because of its geographical location and vulnerability. This report underlines this fact. Undoubtedly, the scientific results presented here merely constitute a first step. There is a need for further research, together with the international scientific community, in order to better grasp the environmental boundaries of our actions and the impacts of greenhouse gas emissions, and to further develop and shape the process and contents of the Netherlands' climate policy. The irreversible nature of the problem obliges us to do so.

Eimert van Middelkoop
Chairman of the 1996 Parliamentary Research Commission on Climate Change
(Voorzitter Klimaatcommissie1996 van de Tweede Kamer der Staten-Generaal),
and Member of the Senate.

Conclusions of the project

Re-evaluating the Netherlands' Long-Term Climate Targets

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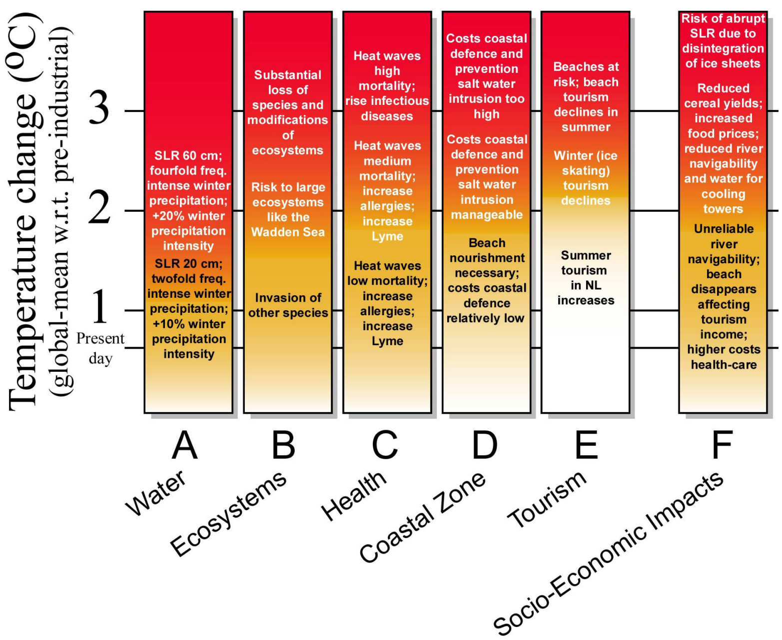
On the basis of the participatory integrated assessment (PIA) of the conditions under which climate change is likely to become dangerous for the Netherlands, this report concludes:

1. Despite the inherent uncertainties in the science, climate change, per se, is seen as a serious environmental problem in the Netherlands;
2. There is a strong preference for articulating the long-term goal in targets and time-tables;
3. On the basis of the PIA, a set of expected long-term impacts on the Netherlands has been tentatively identified. The temperature change with respect to pre-industrial levels are related to the following perceived reasons for concern;



Note: Perceived reasons for concern in the Netherlands. N.B. impacts are for 2100.

4. The mitigation costs are high, but these costs should be evaluated against the costs of (adapting to) climate change impacts. Furthermore, the costs of mitigation measures can be spread over a long time period, and such costs can also lead to innovation and knowledge development.

5. The driving factors for engaging in discussions on dangerous climate change in the Netherlands are the losses to unique ecosystems such as the Wadden Sea and the coastal belt; the high economic, but also socio-political costs of coastal adaptation; the implications of the changing precipitation regime for navigation, agriculture, and infrastructure; impacts on tourism and health; irreversible and abrupt events with high associated risks; and last but not least important - the impacts on vulnerable societies and countries especially in the developing world;
6. 24 indicators have been identified as important indicators of climate change for the Netherlands and these can be prioritised in terms of social and scientific criteria (i.e. are they socially important and scientifically strong) into 7 categories; The above table integrates the scientific and social ranking, but can also be read diagonally. The top left corner shows indicators that are both scientifically sound and socially appealing. The bottom right indicators are less directly attributable to climate change and perhaps less appealing as social indicators but are nevertheless seen as important by social actors. Reading from top left to bottom right, we can identify seven categories of priorities. They are plotted below with respect to two axes, which are ranked from 1 to 5;

	Ranking of scientific criteria				
Ranking of social criteria	**1**	**2**	**3**	**4**	**5**
1		Death from heat waves (A)			
2	Access to clean drinking water; Rate of sea-level rise Allergies (length pollen season) (A)	Water quality (number of weeks one cannot swim) Spread of infectious disease; Floods (B)	Disappearance of species (C)	Change in biodiversity (D)	Social instability (North vs South) (E)
3	Navigability of rivers; Water temperature. (B)	Productivity of land; Effect on work and sectors; No. of ice-skating events (*Elfstedentochten)* (C)	Effect on income (D)	Rate at which the beach disappears (E)	Storms (F)
4	Absolute sea-level rise (C)		Impact on Gulf Stream (E)	Disintegration of Antarctic; Global access to drinking water (F)	Access to food (G)
5	Melting of glaciers (D)				

7. An initial PIA of acceptable risks and threshold levels for the Netherlands is provided below;

Perceived threshold levels in the Netherlands: Results of dialogues and extrapolation.

Priority	Indicator	Acceptable risk	Not acceptable
A	Access to clean drinking water	That there is a temporary ban on washing cars; or watering gardens	That children cannot take baths; or you cannot drink water from the tap;
	Death from heat waves	Mortality remains stable	An increase in mortality
	Allergies and other chronic sicknesses due to longer pollen season		Structural increase in chronic sicknesses
	Rate of sea-level rise	20 cm per century	> 50 cm per century; *> 3 mm per year, because of the devastating effects on the Wadden sea*
B	Water quality (number of weeks one cannot swim)	An increase of 50% from current levels;	An increase of 200%; *Structural effect annually*
	Navigability of rivers	Incidentally less load	Over four weeks less load *Over two weeks less load*
	Water temperature	An incidental rise leading to fish kills	Structural rise leading to loss of biodiversity; *Code red: Electricity is rationed, because of the impact on electricity production*
	Spread of infectious disease	An increases in the chance of falling ill	*If adaptation is no longer possible, or if the costs for adaptation are out of proportion*
	Floods	Incidental increases	Structural increases affecting property values
C	Productivity of land	Incidental losses	*Structural losses*
	Absolute sea-level rise	Marginal increases	> 0.5 m too costly
	Effect on work and sectors	Marginal changes	*Income inequality increases*
	Disappearance of species	Incidental losses	*Where the legal norms are exceeded and structural losses*
	The number of major skating events (*Elfsteden tochten*)	Less than current levels	*Less than once every ten years*

Priority	Indicator	Acceptable risk	Not acceptable
D	Effect on income	Incidental loss of income	No growth as result of impacts for one year; *If Netherlands competitiveness is affected*
	Change in biodiversity	Incidental changes	Loss of key species and ecosystem functions
	Melting of glaciers	Incidental changes	Structural large-scale
E	Impact on the Gulf Stream	Negligible chance	Increase of probability
	Rate at which the beach disappears	When the beach can be easily replenished	*When replenishment is too expensive affecting tourism*
	Instability through North-South impacts	At current levels	Should not increase structurally
F	Disintegration of the Antarctic	Negligible chance	Increase of probability
	Global access to drinking water	Should meet Millennium targets	Should not become worse than today
	Storms	Current levels	Should not increase structurally
G	Access to food	Current problems	When this leads to international instability and significant increase in financial inequality

8. Back-calculating to global temperature levels and concentration levels: Local climate thresholds for impacts need to be converted to global indicators, because of the larger-scale context of global warming and climate policy. For example, temperature change averaged over The Netherlands is projected to increase with a factor of about 1.1 as compared to the global mean. When local impact thresholds have been translated to global indicators, the latter need to be related to GHG concentration targets, before the implications for near- to mid-term emission pathways can be determined. The dominant uncertainty in this step is in the value of the climate sensitivity. This is the equilibrium global-mean surface-air temperature increase resulting from a doubling of the CO_2 (equivalent) concentrations in the atmosphere compared to pre-industrial levels. By use of recent probability estimates of this parameter, risk assessment becomes possible, which is a useful method for evaluating policy options in the context of major uncertainties. In this approach, the question is not which concentration level results in limiting global-mean temperature to a maximum defined by the impact thresholds? Rather, questions like this need to be rephrased to which concentration levels result in a probability of at least x% that global-mean temperature will be limited to a maximum defined by the impact thresholds? Obviously, setting threshold levels and assigning a pursued probability level (x%) is the task of policy makers and stakeholders;
9. Although there are good reasons to focus more on temperature related long-term targets, the project team concluded that both temperature and GHG emission related targets should be considered;

10. Two recent Dutch scientific reports present prima facie contradictory evidence of the feasibility of taking medium-term measures of achieving a –30% reduction of emissions. It appears that while the technological and economic feasibility of reducing emissions is high, stakeholders may not be as supportive. At the same time, some of the large EU member states are also committing themselves to medium and long-term targets in the area of climate change;
11. In response to the key question: what should the Netherlands' perspective be on long-term targets; the scientists concluded that;

    - Beyond 2 °C global warming in relation to pre-industrial levels, there is consensus that the climatic and ecological system could become unstable and irreversible impacts may become inevitable;
    - It should be noted that 2 °C, also implies huge losses to some low-lying countries and some ecosystems;
    - The 2 °C target may already have been exceeded if the sensitivity of the climate system to emissions is higher than currently expected; in other words if the current emissions of aerosols is masking the enhanced greenhouse effect to some extent; (However, the IPCC has not yet made any firm assessment of the situation as yet);
    - Taking all the above into account, it was agreed that on the basis of the current science, a 2 °C target in combination with current expectations that this coincides with a 500-550 ppmv CO_2 eq. concentration level seems to be the most reasonable long-term target for the Netherlands.

    From a political perspective, there were some discussions:

    - Modifying a 2 °C target to a 3 °C target would reduce the urgency for action and increase the risk of instability in the system; this risk was not seen as politically acceptable. Besides, beyond 3 °C the biosphere could become a source rather than a sink of GHGs which could lead to fast, additional increases in atmospheric greenhouse gas concentrations and further, strong temperature changes;
    - Reducing a 2 ºC target to something lower does not seem at all feasible, especially because of the short-term social and economic implications;
    - Should the science indicate that the climate system is more sensitive to emissions this would only imply that the urgency to take measures will increase drastically, and this is an additional argument for not relaxing the 2 °C target;
    - The perspectives of other large EU member states on the issue strengthens the political argument since the Netherlands is then not alone in this perspective.

This research was a cooperative effort of seven research institutes and involved a maximum of 30 stakeholders. The results of this research need to be further discussed and tested with a much more broad group of scientists and stakeholders in order to seek greater accuracy and legitimacy.

Summary

Towards a Netherlands' Perspective on Long-Term Climate Targets

Joyeeta Gupta, Bas Amelung, Harro van Asselt, Marcel Berk, Hendrik Buiteveld, Edwin Dalenoord, Lars Hein, Maud Huynen, Onno Kuik, Rik Leemans, Pim Martens, Jan Mulder, Albert Oost, Michiel Schaeffer; Koos Verbeek and Mick van der Wegen.

The problem of a long-term target

The United Nations Framework Convention on Climate Change of 1992 (FCCC 1992) has adopted a long-term target of stabilizing greenhouse gas emissions:

> *"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."*

However, the above text does not specify by when and at what level concentrations should be stabilized. It does, though, give certain conditions. More than a decade has passed since the Convention was adopted and the climate regime is inching forward with targets to control the emission levels of countries. The question is: Are these targets in line with the efforts needed to control climate change before it becomes too dangerous? Or given the inertia in the climate system, are these targets far too low and an inadequate response to the climate change problem.

Recognizing this problem, the Netherlands government interpreted Article 2 of the FCCC as follows:

- The global average temperature should not rise above a maximum of 2 ºC of pre-industrial levels;
- The rate of temperature change should be less than 0.1 degrees Celsius per decade; and;
- Sea-level rise should be limited to a maximum of 50 cms (VROM, 1996: 88-89).[1]

In preparing for the Kyoto negotiations, the EU Council also adopted a long-term climate policy goal to limit global warming to less than 2 ºC and a concentration level of

[1] The IPCC reports show that the average annual temperature is 15 ºC. In the last 900.000 years the global average temperature was never higher than 17 ºC. The last 10.000 years the temperature variations were smaller than 2 ºC. Ecosystems can adapt naturally to climate change, without the loss of biodiversity, if the increase of temperature is less than 0.1 ºC per decade.

550 ppmv of CO_2 emissions (EC, 1996).[2] Since then these policy goals have not been re-evaluated, although new targets are being discussed and will be adopted in 2005.

The question now is: Are these targets still valid given the new science available and the perspectives of key social actors?

Towards a PIA approach for analysing 'dangerous interference' with climate change

Methodologically, two points are of vital importance:

- The first is that 'dangerous' is not a term that can be defined by scientists alone, since danger is a question of the risk societies are willing to take in relation to an expected problem. It is a question that can only be articulated through a process of discussion and dialogue between social actors. This calls for the use of concepts and tools from public interest science, post-normal science and participatory integrated assessment (PIA)[3];
- The second point is that since the impacts of climate change will not be similar nor evenly experienced all over the world and across generations, the danger levels associated with climate change will be different to different countries and to different ecosystems. From a political perspective there are two issues: - the first is that although climate change is seen as primarily a global problem, politically there has been a tendency to see adaptation as primarily a local problem (Bodanksy, 1993). The second is that there is a governance structure for global problems in which states negotiate primarily on the basis of national interests, although the problems may well be perceived as global. This implies that there is a fundamental mismatch between the global scale of the problem and the national scale interests on the basis of which the problem is being dealt with.

Thus, in order to determine the Netherlands perspective for the long term it is of importance:

- To assess the available science in terms of primarily impacts on the Netherlands;
- Undertake a science-policy dialogue; and;
- Highlight how social actors perceive the impacts at global to local levels.

There are two ways of discussing long-term targets. One is to begin with national positions on concentration levels and then understand the underlying arguments and values; the other is to begin with indicators of impacts, identify threshold levels and work back to concentration levels (see Figure 1).

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2 These two are not compatible goals and possibly reflects a compromise between those who wanted the tougher target of 2 ºC (equivalent to a 450 ppmv CO_2 emissions and 550 ppmvCO_2.eq., and those who wanted a weaker target).

3 These scientific theories call for integrating participatory approaches in normal scientific practice in order to increase the value of the scientific results. Such approaches are in particular considered relevant where the public interest is important, where the science is uncertain, the risks high and decisions urgent.

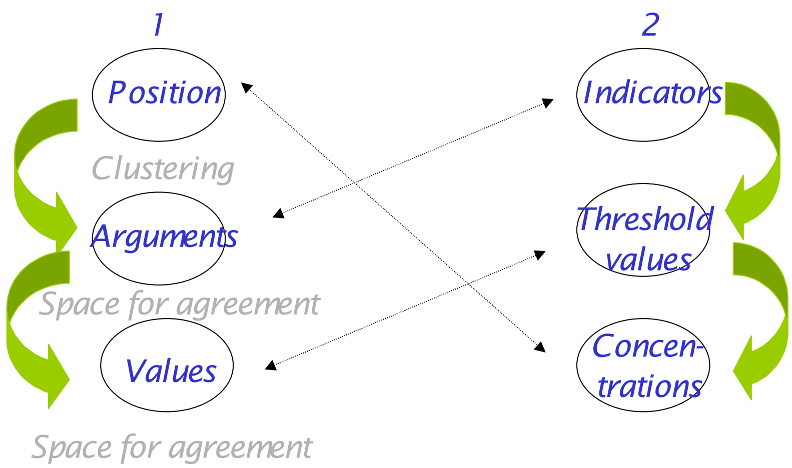

Figure 1. The two approaches for analysing long-term targets.

In this project, we chose the latter method. This is because the specific philosophy of this project was that discussing a long-term target in terms of concentration levels (450 ppmv - 1000 ppmv) or temperature levels (0.5 °C rise - 3 °C rise) is too abstract for most people to react to. It would make more sense to talk in terms of indicators of climate change impacts that people can directly relate to in their daily lives. The first step was to identify on the basis of a study of the impacts of climate change on the world, Europe and the Netherlands, what would be the possible types of indicators that are of scientific significance for the Netherlands. The stakeholder discussions would help to identify the key indicators that are likely to have a greater appeal to members of society. Having first identified what are the most important indicators from a *Netherlands' perspective*, we then tried to develop arguments about the possible reasons why people should choose for a certain threshold level for danger in relation to each indicator. Having spent a second session discussing these with key stakeholders, we then tried to use the key arguments generated by the stakeholders in discussion with the scientists to identify indicators, rank them in order of social and scientific importance, attribute threshold values to these and then see if we could make links back to concentration levels/ temperature and hence emission levels. The back-calculation approach used in this project can be shown in Figure 2.

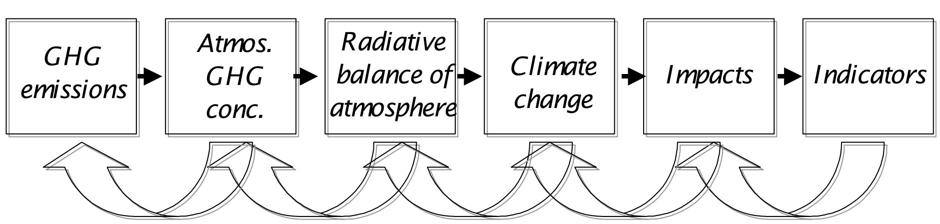

Figure 2. Back calculating from impacts to emission levels.

In order to address the assessment questions, the project team chose a participatory integrated assessment method. In our interpretation of this method, we first defined the problem, then we assessed the science and stakeholder inputs. We summed up the scientific information available on the problem of climate change with a special emphasis on the impacts on the Netherlands in fact sheets. We undertook interviews with stakeholders in the Netherlands on the need for long-term targets and possible definitions thereof. We organized two rounds of workshops with stakeholders, at which the latest scientific information was presented, to allow for a science-policy dialogue. The purpose of providing this information to the stakeholders and listening to their views on the subject was to understand the arguments that play a prominent role among stakeholders in deciding how the long-term goal of the Netherlands should be articulated. On the basis of this dialogue we identified relevant indicators for the Netherlands, threshold levels for dangerous impacts, and back-calculated to the possible concentration levels and long-term targets on climate change. In other words we decided to take a *Netherlands' perspective on climate c*hange (see Figure 3).

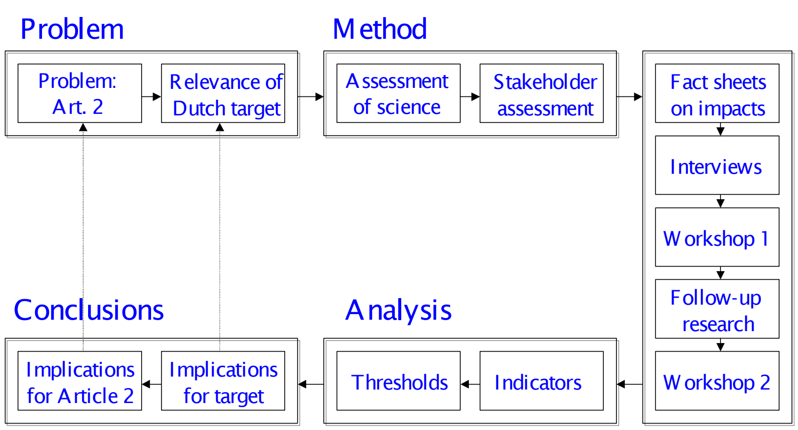

Figure 3 The structure of the project.

A Netherlands' perspective on the impacts of climate change

Climate change is seen as a serious problem

The first critical question is: Is climate change seen as a serious problem within the Netherlands?

An assessment of the current state of the science on climate change shows that that there has been an increase in the global temperature in the last millennium and in the last century; that these changes can be related with observed changed in the global atmospheric composition, and it is very likely that there will be a rise in temperature and accompanying impacts in the 21^{st} century and beyond (IPCC WG 1, 2001). The scientific community in the Netherlands has confidence in these results.

There are some sceptics in the Netherlands whose key arguments are that the scientific reports are politically motivated consensus reports, and thereby not scientific; that the use of the word uncertain throughout these reports shows how bad the science is; that there is empirical evidence which is allegedly not being taken into account; that certain scientific results and certain scientists are excluded from the process; that IPCC scenarios are based on unrealistically high growth rates for the South, and that in the final analysis the costs of taking measures are so high and the returns so low, that it does not make sense to take measures (Labohm et al., 2004).

The response to these questions were that the IPCC reports represent the best available science; and that the consensus concerns the description of the scientific literature, not the science as such (i.e. the scientists agree to disagree on many points); that the use of the word uncertainty reflects the integrity of the scientists and not the dubious nature of the science; that nothing is *a priori* excluded and as new scientific evidence emerges it will be taken into account; that the scenarios of future emissions do assume that developing countries will become richer in the future; and that even though the costs of taking measures are high relative to the possible impacts especially in the case of the Kyoto Protocol, it merely represents an (important) first step (Gupta et al., 2004).

A debate between the stakeholders revealed that once the critique of the climate change science was made transparent, the stakeholders still perceived the climate change problem as a serious problem, meriting substantial action.

There is a strong preference for articulating the long-term goal in targets and timetables

The second critical question is: Should we frame the long-term climate change problem in terms of targets and timetables?

The issue of long-term targets and timetables was brought to the fore in 1992 in Article 2 of the UNFCCC. Since then, there has been no real articulation of this Article. This, in itself, reflects the political difficulties in attempting to do so. The literature reveals that those opposing targets and timetables argue that there is incomplete knowledge, diverging impacts world-wide, different values in assessing risks, and since such a long-term target is closely linked with issues of how responsibilities will be divided among countries. Therefore, they argue that it would be impossible to come to (a) a scientific evaluation of what is dangerous; and (b) political consensus at the global level on what is dangerous. Besides they argue that stabilizing concentrations of GHGs, does not lead directly to a stabilization of the impacts. The sea level will continue rise for a long time thereafter. Meeting the Kyoto targets is a first, small step towards stabilizing concentrations, so small that critics doubt the usefulness of such a step. Hence, the argument is that efforts can best be channelled into alternative mechanisms for reducing emissions, instead of getting bogged down in intractable controversies (e.g. Pershing & Tudela, 2003). President George Bush articulated this sentiment as follows: "No one can say with any certainty what constitutes a dangerous level of warming, and therefore what level must be avoided"[4]

Others argue that the adoption of a long-term quantified objective will provide the scientific rationale for the political process, will provide the framework for countries to see if they are on track towards achieving these goals, ensure that the negotiations are on track, and send clear signals to industry and society. They quote the precautionary principle that lack of scientific evidence should not stand in the way of decisions especially where irreversible effects are expected. Finally, the methodological objections are shortsighted

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[4] http://www.whitehouse.gov/news/releases/2001/06/20010611-2.html.

since participatory integrated assessments help in assessing such ‘unstructured’ and ‘wicked’ problems (cf. Rijsberman & Swart, 1990; Evans, 2002; Gupta et al., 2003).

The Netherlands’ government is inclined towards adopting long-term targets as can been seen from the 1996 report (VROM, 1996) and the re-emergence of the idea of discussing medium term targets in political discussion in 2004. The adoption of the target did not lead to significant protests in the Netherlands and that can be seen as *prima facie* evidence that stakeholders either support the view or trust the government’s perspective on this. Stakeholders participating in this process did see Article 2 as important and their participation indicates that most felt that, despite the scientific and social challenges in the process, an effort had to be made to identify what would be dangerous to the Netherlands and global society. They argued that unacceptable outcomes of climate change would include irreversible outcomes, loss of inhabited land in some parts of the world, loss of growth opportunities in developing countries, and high economic costs to the rich countries. In theory, a long-term target is useful because it helps to match long-term scientific and short-term political scales, and provides the justification for short-term action. In practice this does not automatically imply that the long-term targets will be acceptable to all. Although for industry stakeholders the long-term target does not necessarily pose a problem, since it is in line with current short-term targets of some industry, they might not accept strong medium-term targets. For the insurance industry, the perception shared was that there is no real problem, because if the impacts increase the industry will increase the premiums; in other words they can adjust fairly easily. The critical issue of the Ministry of Economic Affairs appears to be the effect on the Netherlands’ ability to compete on the international market, especially in the context of US non-participation in the regime.

There are clear long-term scenarios of expected impacts on the Netherlands

The third critical question is: what are the likely scenarios for the Netherlands? The Royal Netherlands Institute for Meteorology (KNMI) has prepared three scenarios for the possible impacts on the Netherlands that corresponds to different levels of temperature rise in 2100. These are shown in Table 1.

Table 1. KNMI Climate scenarios for the Netherlands in 2100.

Temperature	+1ºC	+2ºC	+4 to +6ºC
Mean summer precipitation	+1%	+2%	+4%
Summer evaporation	+4%	+8%	+16%
Mean winter precipitation	+6%	+12%	+25%
Intensity in winter precipitation	+10%	+20%	+40%
Frequency of intense winter precipitation	2 times as high	4 times as high	10 times as high
Sea-level rise	+20 cm	+60 cm	+110 cm

Note: These values are relative to 1990 levels.

Scientists perceive the following impacts as critical for the Netherlands

The fourth question is: What are the likely impacts on the Netherlands?

Global warming increases temperatures and thereby interferes with the hydrological cycle. These changes will affect food production, access to water, ecosystems, health, tourism and the coastal zones.

The Netherlands will be seriously affected by the changes in the water system. It is expected, for example, that the winter discharges into the Rhine and Meuse will increase, while the summer discharge will decrease. A rising sea level will hamper the discharge into the sea. The seepage and salinity in areas around the IJsselmeer is expected to increase. Inundations and salt-water intrusion will become more common. There will be water shortage in the summer (see Table 2). Rising temperatures and falling quantities will affect the availability of cooling water for industry and the power plants.

Table 2. Water shortage.

Shortage Soil				Shortage surface water		
Present	Present	2050(+1°)	2050(+2°)	Present	2050 (+1°)	2050 (+2°)
Average year	21	25 (+19%)	28 (+36%)	5,7	5,8 (+2%)	6,0 (+4%)
Extreme dry year	143	153 (+8%)	165 (+17%)	12,4	11,7 (-6%)	12,2 (-2%)

Source: Arcadis et al., 2002.

Specialized species (species with specific environmental needs) and the least mobile species are likely to be seriously affected, and less specialized species will flourish. We can already see sub-tropical and tropic lichen species in the Netherlands. For each degree warming, tree lines will shift 300 km pole-wards and about 15-20% of all terrestrial vegetation will change composition. The increased warmth may lead to a lengthening of the pollen season. A 1ºC increase in water temperature can lead to the death of coral reefs. These impacts could lead to species extinction and alteration of ecosystems.

Although the flooding is unlikely to have serious physical human health consequences, the psychological effects may be quite severe. Higher temperatures may lead to increased mortality. Longer pollen seasons could lead to increase in chronic sicknesses such as allergies and asthma. Vector-borne diseases are likely to increase, in particular the Lyme disease.

In winter, climate change could have an effect on the number of ice-skating events (e.g. *Elfstedentocht*). While tourists and tourism services may be flexible, tourism infrastructure is more vulnerable. A rising sea level implies a coastal squeeze (more pressure on "soft" coastal areas like wetlands and beaches combined with an increase in hard protection measures like the construction of sea dikes). Large infrastructural investments will be necessary to protect the Netherlands. Changes in the global climate may have a strong impact on the coastal zone by the changes in hydrology (river discharges into open sea), hydraulic phenomena (wave/storm-climate, sea level and sea-level rise), morphology (sedimentation patterns, coastal retreat), ecology (terrestrial and marine) as well as many aspects of human use (safety, socio-economic developments).

Possible impacts on the Netherlands can be tentatively visualised as follows:

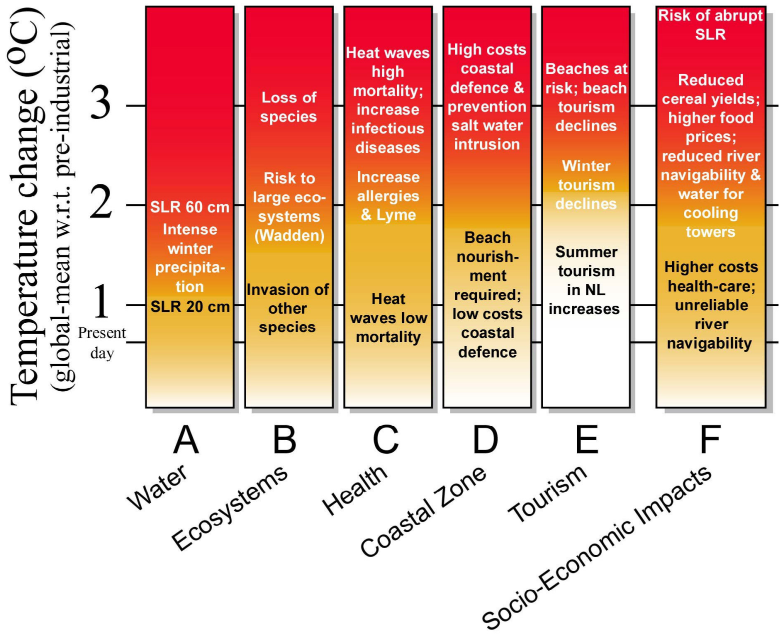

Figure 4. Perceived reasons for concern in the Netherlands.

Note: Perceived reasons for concern in the Netherlands N.B. The impacts are for the end of the 21st century. This is a more communicative version of the original, more scientifically sound figure, which can be found in Chapter 8.

Adaptation options to climate change: A proactive approach necessary

The fifth question is: what are the adaptation possibilities for climate change? The adaptation options for climate change have been examined on the basis of the stakeholder consultations, as well as through an assessment of current scientific understanding of adaptation options. During the stakeholder consultation process, stakeholders discussed potential types of adaptation options, and priorities in the implementation of adaptation measures. Based upon the stakeholder participation process, the main adaptation options have been further examined on the basis of recent scientific literature.

We examined the adaptation options for climate change on ecosystems, food production, water management, health, tourism and coastal zone management. For ecosystems, the most important adaptation option is to ensure the resilience of ecosystems in order to ensure the maintenance of their capacity to cope with the climate change induced modifications of their abiotic environment. Besides climate change, ecosystems are also under threat from a range of other factors that lead to the loss of species and modification of ecosystems, such as pollution, land use conversion, and overexploitation. Reducing these other threats will in many cases be easier and less costly, than reducing the impacts of climate change. Agricultural systems can adapt to climate change through changes in crop choice, water management, reclamation of land, research programs and organisation structure. Some farm level adaptation strategies, such as changes in planting and harvest dates, crop rotation and crop varieties, can be incorporated without large changes in management practises. The adaptation to extreme events is particularly cumbersome, this requires timely action and long-term capital investments, e.g. in water storage reservoirs. Costs of adaptation options for ecosystems and the agricultural sector are, as yet, not known in detail. Regarding water management, adaptation will require substantial investments in upgrading the retention, storage, and discharge systems. The cost which are needed in water management in dealing with floods and droughts amount to some €1.2 billion, based on the +2 °C climate scenario for the year 2100. Possible adaptation strategies to mitigate the health effects of climate change cover a wide spectrum, including adapted building regulations, enhanced urban planning, early warning systems and improved water quality treatment systems. This requires substantial changes in our regulatory framework, as well as expensive adaptations to our building infrastructure. For the tourism and recreation industry, the adaptation options depend upon the response of tourist to changing climatic conditions, It is generally expected that they will become more flexible in booking a holiday as a result of uncertain weather in their potential holiday locations. In addition, specific investments may be required to offset the impacts of additional smog, extreme events, or to adjust the environment e.g. through (energy intensive) snow canons on ski-pistes. The coastal zone's response is largely depending on the rate of external changes, in particular sea-level rise. Adaptation is required, in particular, to maintain the shoreline and decrease coastal erosion rates. A strategic and proactive approach to coastal erosion is needed for the sustainable development of vulnerable coastal zones and the conservation of coastal biodiversity.

Costs, however important, are seen as complex and relative

The sixth question is: What will all this cost and how should we deal with the cost issue?

In determining the costs of climate change, one needs to add the costs of mitigation of net GHG emissions, costs of adaptation to the impacts, and the costs of the residual impacts. The more one invests in mitigation, the less the other two costs are at a global level. At a national level, the relation is less clear. In determining costs, one needs to have a baseline scenario of how societies would otherwise have developed, information about the policy regime, the flexibility of the economic and energy systems and the institutional infrastructure, the rate and nature of technological progress in mitigation technology and the co-benefits of mitigation measures. There are so many uncertainties in all these issues that the projections of costs become a complex issue.

The total discounted costs of stabilizing emissions at 450 ppmv have been estimated to lie between US$ 2.5-18 trillion dollars; at 550 ppmv they have been estimated to be about US$ 1-8 trillion and for 650 ppmv about a range of US$ 0.5 to 4 trillion has been estimated (IPCC 2001). But these costs do not take into account the lower need for costly adaptation measures, nor do they take account of the damage costs of climate change impacts. Cost estimates of the stabilization target of 550 ppmv for Europe range from direct mitigation costs of 0.5 to 1 percent of GDP to income losses of 2 to 6 percent of GDP in 2040. For the world these estimates range from 1 percent, respectively 1 to 5 percent of GWP in 2040. If co-benefits are taken into account costs may reduce substantially.

Such numbers are seen differently. If compared to current world income of 20 trillion per year, the investment appears gigantic. If viewed in terms of the delay in economic growth, the costs appear to be reasonable.

Given all these considerations, one can argue that mitigation cost estimates cannot readily be used as thresholds, in the sense of "this cost is clearly too high" or "this cost is just acceptable". Nevertheless, policy makers need advice on the costs of policy.

Although the stakeholders argued in favour of having the best available knowledge on costs of policies, during the discussions of indicators and thresholds, they found that they were able to engage in a useful elaboration of arguments of why a particular outcome was unacceptable, independent of the costs. The key cost challenge for the Netherlands was articulated in terms of the loss of competitiveness argument in relation to other countries such as the US.

The driving factor for engaging in discussions in the Netherlands

The seventh question is: What are the driving factors for the Netherlands in engaging in discussions on abating climate change?

The project shows that the Netherlands will be most seriously affected by the impact on the water system and then associated impacts. However, most of these impacts did not appear to be in themselves very serious, and it did appear that technically speaking the Netherlands could possibly cope with many of the impacts. However, stakeholder argued that a passive attitude could not be justified because:

- This did not take the loss of biodiversity at national to global levels into account;
- The costs of adaptation for the low-lying parts of the Netherlands would not be negligible;
- The mere fact that Netherlands can technically deal with the rising sea-level, does not mean that the society wants to be locked within high walls;
- The irreversible and abrupt events had very high associated risks and these needed to be avoided at all costs; and
- The Netherlands cannot be seen as an isolated actor in the international society, and it needs to take into account impacts that occur elsewhere;

24 indicators ranked in six categories are seen as relevant for the Netherlands

The eight' question is: What are the relevant indicators for the Netherlands, and how can one rank them?

On the basis of the scientific information, stakeholders identified 21 national level indicators and 3 international level indicators. These include:

- Water quality: The problem of blue algae and botulism are seen as serious threats to water quality in the Netherlands and will affect the recreation and tourism industry by making water unsafe to swim in;
- Access to water: There is an expectation that the quality and quantity of water available to the households may be reduced by climate change, leading to restrictions in water use;

- Navigability of rivers: Climate change is expected to have an influence on water levels in the navigable rivers thus influencing transport in the rivers and the transport sector as a whole;
- Water temperature: The rise of the water temperature may both affect biodiversity and fish stocks and have socio-economic impacts, through the rationing of electricity related to cooling water availability;
- Agricultural productivity: Climate change is likely to influence agricultural productivity by influencing the quality and quantity of water available for crops;
- Absolute sea-level rise: Climate change is expected to lead to a rising sea level; this continuous rise is expected to have a continuing impact on the Netherlands, long after concentration levels are stabilized;
- Rate of sea-level rise: An absolute sea-level rise implies that the sea-level is rising continuously. This is of immediate relevance to defining response actions of society;
- Spread of infectious disease: A rise in local temperatures may be accompanied by the spread of infectious diseases; the most serious identified threat was the Lyme disease spread by ticks. This could influence both the health sector and recreation possibilities;
- Death from heat waves: Another potential impact of the rise in summer temperatures is the rise in death rates especially of senior citizens. This may, however, be compensated by a decrease in death rates in the warmer winter months;
- Increased length of the pollinating season: It is anticipated that the length of the pollinating season will increase; if so this will have immediate impacts on chronic sicknesses such as allergic responses and asthma;
- The rate of disappearance of beaches: A rising sea level can be dealt with by building dikes and dams (although at considerable cost), but not without severe consequences for beaches in the Netherlands. This will have impacts on the recreation and tourism sector;
- Reduced opportunities for ice-skating: With warming, there will be reduced opportunities for ice-skating and especially the 11 cities ice-skating event that the Dutch are so keen on;
- The effects on national income: There is an expectation that unilateral policy action in the Netherlands will have negative impacts on national income;
- The effect on other macro-economic factors, such as employment, vulnerable sectors, growth rates: Some sectors may in particular be vulnerable especially if energy prices rise as a result of energy related choices. As a counter effect climate change measures may have a positive spin-off;
- Floods: Extreme events will lead to, *inter alia*, floods in the Netherlands. Such flooding can have large consequences on infrastructure as well as human health and society;
- Storms: Other extreme events include storms. These are not expected to have quite as severe an impact as floods in the Netherlands;
- Changes in the biodiversity: The biodiversity in the Netherlands is expected to change with the changing environment;
- Melting of glaciers: Glaciers are projected to continue their widespread retreat during the 21^{st} century;
- Disintegration of the West-Antarctic ice sheet leading to a 1 metre extra sea-level rise per century for many centuries: An important international impact that is of

direct relevance to the Netherlands is the possible disintegration of the West Antarctic ice sheet and its influence on the Netherlands;
- Changes to the Gulf Stream: Another impact is the possibility of a major change to the North Atlantic warm gulf stream leading to significant changes in the European climate;
- The disappearance of species: It is expected that ecosystems in Europe will shift pole ward by 300 kilometres for every degree warmer. This will lead to a gradual extinction of species in this part of the world. Particularly vulnerable regions in the Netherlands include the Wadden Sea.

Indicators purely of an international nature that were also seen as critical for the Netherlands included:

- Access to drinking water world-wide: Current access to drinking water world-wide is already a serious problem as recognized by the Millennium Development Goals; but it is expected that the climate change problem will exacerbate the situation much further;
- Access to food world-wide: As a result of changing temperatures and rainfall patterns, local access to food will also probably change negatively in most parts of the developing world;
- Impacts on North-South equity per se: The impacts of climate change are expected to be highly visible in the developing world. Coral reefs are already bleaching, glaciers are already melting and rainfall patterns are changing. This is expected to have a negative influence on the security in developing countries, and may have negative repercussions on the developed world.

On the basis of a social and scientific ranking process stimulated by the stakeholder discussions, the indicators can be prioritised as follows (Table 3). This table integrates the scientific and social ranking, but can also be read diagonally. The top left corner shows indicators that are both scientifically sound and socially appealing. The bottom right indicators are less directly attributable to climate change and perhaps less appealing as social indicators but are nevertheless seen as important by social actors. Reading from top left to bottom right, we can identify seven categories of priorities.

Speculating on acceptable and non-acceptable threshold levels for society

The ninth question is: What are appropriate threshold levels per indicator?

On the basis of the science-policy dialogues, we were able to reach an initial analysis of possible acceptable risks and threshold levels. The information in this table is based on the work of different break-out groups and extrapolations on the basis of the arguments made during the workshops. The latter was necessary as the break-out groups were not able to discuss all the different indicators at great detail; but there was a clear line in the arguments. These are shown in Table 4.

Table 3. Prioritising on the basis of the ranking of scientific and social criteria.

Ranking of social criteria	Ranking of scientific criteria: 1	2	3	4	5
1		Death from heat waves (A)			
2	Access to clean drinking water; Rate of sea-level rise Allergies (length pollen season) (A)	Water quality (number of weeks one cannot swim) Spread of infectious disease; Floods (B)	Disappearance of species (C)	Change in biodiversity (D)	Social instability (North vs South) (E)
3	Navigability of rivers; Water temperature. (B)	Productivity of land; Effect on work and sectors; No. of ice-skating events (*Elfstedentochten*) (C)	Effect on income (D)	Rate at which the beach disappears (E)	Storms (F)
4	Absolute sea-level rise (C)		Impact on Gulf Stream (E)	Disintegration of Antarctic; Global access to drinking water (F)	Access to food (G)
5	Melting of glaciers (D)				

Table 4. Perceived threshold levels in the Netherlands: Results of Dialogues and extrapolation

Priority	Indicator	Acceptable risk	Not acceptable
A	Access to clean drinking water	That there is a temporary ban on washing cars; or watering gardens	That children cannot take baths; or you cannot drink water from the tap;
	Death from heat waves	Mortality remains stable	An increase in mortality
	Allergies and other chronic sicknesses due to longer pollen season		Structural increase in chronic sicknesses
	Rate of sea-level rise	20 cm per century	> 50 cm per century; *> 3 mm per year, because of the devastating effects on the Wadden sea*
B	Water quality (number of weeks one cannot swim)	An increase of 50% from current levels;	An increase of 200%; *Structural effect annually*
	Navigability of rivers	Incidentally less load	Over four weeks less load *Over two weeks less load*

	Water temperature	An incidental rise leading to fish kills	Structural rise leading to loss of biodiversity; *Code red: Electricity is rationed, because of the impact on electricity production*
	Spread of infectious disease	An increases in the chance of falling ill	*If adaptation is no longer possible, or if the costs for adaptation are out of proportion*
	Floods	Incidental increases	Structural increases affecting property values
C	Productivity of land	Incidental losses	*Structural losses*
	Absolute seal level rise	Marginal increases	> 0.5 m too costly
	Effect on work and sectors	Marginal changes	*Income inequality increases*
	Disappearance of species	Incidental losses	*Where the legal norms are exceeded and structural losses*
	The number of major skating events (*Elfsteden tochten*)	Less than current levels	*Less than once every ten years*
D	Effect on income	Incidental loss of income	No growth as result of impacts for one year; *If Netherlands competitiveness is affected*
	Change in biodiversity	Incidental changes	Loss of key species and ecosystem functions
	Melting of glaciers	Incidental changes	Structural large-scale
E	Impact on the Gulf Stream	Negligible chance	Increase of probability
	Rate at which the beach disappears	When the beach can be easily replenished	*When replenishment is too expensive affecting tourism*
	Instability through North-South impacts	At current levels	Should not increase structurally
F	Disintegration of the Antarctic	Negligible chance	Increase of probability
	Global access to drinking water	Should meet Millennium targets	Should not become worse than today
	Storms	Current levels	Should not increase structurally
G	Access to food	Current problems	When this leads to international instability and significant increase in financial inequality

Back-calculating to global temperature levels and concentration levels

Local climate thresholds for impacts need to be converted to global indicators, because of the larger-scale context of global warming and climate policy. For example, temperature change averaged over the Netherlands is projected to increase with a factor of about 1.1 as compared to the global mean. When local impact thresholds have been translated to global indicators, the latter need to be related to GHG concentration targets, before the implications for near- to mid-term emission pathways can be determined. The dominant uncertainty in this step is in the value of the climate sensitivity. This is the equilibrium global-mean surface-air temperature increase resulting from a doubling of the CO_2 (equivalent) concentrations in the atmosphere compared to pre-industrial levels. By use of recent probability estimates of this parameter, risk assessment becomes possible, which is a useful method for evaluating policy options in the context of major uncertainties. In this approach, the question is not which concentration level results in limiting global-mean temperature to a maximum defined by the impact thresholds? Rather, questions like this need to be rephrased to which concentration levels result in a probability of at least x% that global-mean temperature will be limited to a maximum defined by the impact thresholds? Obviously, setting threshold levels and assigning a pursued probability level (x%) is the task of policy makers and stakeholders.

Temperature or concentration targets

The next question is whether one should focus on temperature levels, concentration levels or a combination of the two. In case the GHG concentrations are stabilized at 650 ppmv the temperature increase will only remain below 2 ºC if the climate sensitivity is low. With a high climate sensitivity of 4.5 ºC, neither stabilization levels will meet the 2 ºC target. To some extent, these time-dependent results also depend on the climate model used. For stabilization at 550 ppmv CO_2-eq. the probability of limiting temperature increase to 2 ºC is about 33% and 50% respectively. For stabilization at 650 ppmv, this decrease to about 10 - 33%. A 100% probability is unachievable, because of the uncertainty in probability estimates, but also because of other uncertainties in the climate change cause-and-effect chain than assessed in this report. An important observation is that the probabilities depend non-linearly on concentration levels. For the 2ºC target the probability of achieving this target increases most rapidly with decreasing concentrations at medium-to-low stabilization levels.

Because of large inertias in the climate system, the full temperature consequences of sustained variations in radiative forcing are not felt for many decades to centuries. Therefore, if concentrations are lowered immediately after stabilization, the full consequence of the peak concentration is moderated. In the light of these inertias, long-term stabilization of GHG concentrations might therefore not be the most sensible target, especially since temperature change is also a more appropriate indicator of climate change impacts concentrations might not be the most sensible target.

Current estimates shows that in order to stabilize GHG concentrations at 550 ppmv CO_2-eq. global anthropogenic emissions (including both energy, industry and land use emissions) will have to peak before 2020 at a level about 35% above 1990 levels. By the 2030s emissions would need to have returned to 1990 levels. For stabilizing at 650 ppmv

CO_2-eq. global emissions could peak later at a higher level and need to return to 1990 levels at a much later stage. Low stabilization levels leave little room for optimisation: e.g. for stabilizing at 550 ppmv CO_2-eq. the global emissions need to peak within 20 years from the present-day, or concentrations will exceed this level. At higher stabilization levels emission profiles can be varied concerning gas mixture and/or over time, including reduction delays compensated by steeper reductions later on.

In response to the question, should the focus of a long-term target be on concentrations, temperatures or something else, the arguments were as follows:

- A focus on global-mean temperature is useful in that it is logical from a scientific perspective, closer to impacts, representative of a number of impacts, easy to verify, understandable; even if not entirely appealing and too abstract for society;
- A focus on concentrations is useful because it relates directly to emission levels, even though it is more abstract for society and somewhat further away from impacts.

It would appear that the stakeholders were somewhat neutral on this.

What are other countries doing?

The Netherlands is a small country with marginal emissions. It does not make political sense to investigate how the Netherlands should examine the long-term objective of the climate change target, if we do not know how other countries perceive the issue.

The US clearly is not inclined to investigate long-term targets at the present moment. On the other hand, the EU is looking into this issue. This is not just an aberration in behaviour, but can be traced back to the political approaches of both countries (Kagan, 2004). Within the EU, initial research shows that not only does the EU itself has a target dating back to 1996, the UK, Sweden, France and Germany have identified long-term and short-term conditional targets. The French and Germans seem to like to limit warming to 2 °C and concentration levels to 450 ppmv CO_2.

The UK and Sweden appear to be moving towards a –60% reduction for the developed countries in 2050 in relation to 1990 levels. Germany is considering a –40% reduction in 2025 if other EU countries commit to a 30 % reduction. The Netherlands' government is politically exploring the possibility of a –30% reduction in 2020.[5] A recent Netherlands report argues against such a target, because it appears to be unfeasible at the moment from a stakeholder perspective (Hisschemöller & van de Kerkhof, 2004). However, another Dutch report (Bollen et al., 2004) argues that a reduction of 30% in relation to 1990 levels is feasible at reasonable costs if emission trading is allowed.

Policy recommendations

Having slowly worked our way back to the long-term targets, the key question is: what should the Netherlands' perspective be on long-term targets?

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[5] Tweede Kamer, 2003-2004, 28240., Nr. 5.

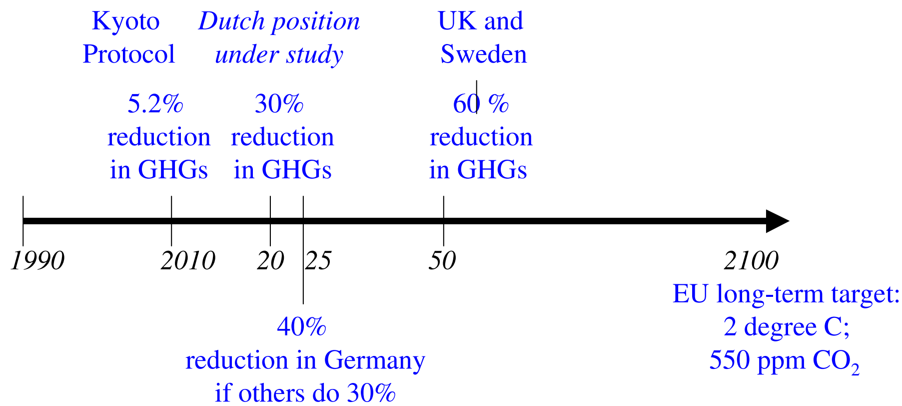

Figure 4. Current positions of countries on long- and short-term targets.

The scientists concluded that:

- Beyond 2 ºC global warming in relation to pre-industrial levels, there is consensus that the climatic system could become unstable and irreversible impacts may become inevitable;
- It should be noted that 2 ºC, still implies huge losses to some low-lying countries and some ecosystems;
- The 2 ºC target may already have been exceeded if the sensitivity of the climate system to emissions is higher than currently expected; in other words if the current emissions of aerosols is masking the enhanced greenhouse effect to some extent; (However, the IPCC has not yet made any firm assessment of the situation as yet);
- Taking all the above into account, it was agreed that on the basis of the current science, a 2 ºC target in combination with current expectations that this coincides with a 500-550 ppmv CO_2-eq. concentration level seems to be the most reasonable long-term target for the Netherlands.

From a political perspective, there were some discussions:

- Modifying a 2ºC target to a 3 ºC target would reduce the urgency for action and increase the risk of instability in the system; this risk was not seen as politically acceptable. Besides, beyond 3 ºC the biosphere could become a source rather than a sink of GHGs;
- Reducing a 2 ºC target to something lower does not seem at all feasible, especially because of the short-term implications.[6];
- Should the science indicate that the climate system is more sensitive to emissions this would only imply that the urgency to take measures will increase drastically, and this is an additional argument for not relaxing the 2ºC target;
- The perspectives of other large EU member states on the issue strengthens the political argument since the Netherlands is then not alone in this perspective.

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[6] Even a 2°C target appears less feasible in the Dutch context, according to a selection of Dutch stakeholders (see Hisschemöller and van de Kerkhof, 2004, on the feasibility of a –30% target in 2020).

Research recommendations

There are a number of items that need to be further researched. These include:

- Further scientific research to increase knowledge about regional climate change and the associated impacts;
- Considerable uncertainty exists in the estimates of the probability distribution of the climate sensitivity. An evaluation of the differences between currently applied methodologies and an assessment of the associated reliability is recommended;
- In the past decade, most research effort has been put into estimating mitigation costs associated with stabilization of greenhouse-gas concentrations. New research is required to evaluate peaking and overshoot profiles that might provide more cost-effective options to achieve the same long-term climate targets;
- Probability estimates, concentration estimates, and assessments of emission pathways and associated emission reduction costs are currently performed as single issues by different (modelling) tools and research groups. An integrated (modelling) framework capturing all these issues is required in the light of inconsistencies like different baseline scenarios, reduction options, greenhouse-gas mixtures and climate system characteristics;
- Further scientific research and discussions with national stakeholders on further elaboration of and the robustness of the threshold levels for the indicators;
- In addition, in order to gain momentum for the political action needed, global science-policy dialogues on long- term targets need to be supported. This is necessary since the negotiations are continuously focused on short-term goals and the long-term perspective is often lost.

Final comment

This research was a cooperative effort of seven research institutes and involved a maximum of 30 stakeholders. The results of this research need to be further discussed and tested with a much more broad group of scientists and stakeholders in order to seek greater accuracy and legitimacy.

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1. Introduction and problem definition

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1.1 Introduction

This document assesses the existing literature in order to be able to come to an articulation of possible long-term policy goals for the Netherlands' government in the area of climate change. A participatory method has been chosen in assessing the existing literature in order to identify the possible arguments and choices that stakeholders may make in favour of a particular definition of risk of danger. This document provides information on how Article 2 of the United Nations Framework Convention on Climate Change (FCCC 1992) can be articulated, and specific information about whether and how the Netherlands' government's own articulation of the long-term goal can be updated in the light of new scientific information and an assessment of stakeholder perceptions. The information aims to be both scientifically sound and easily usable by policymakers and stakeholders.

1.2 Background: the problem

The climate change problem is being addressed through the United Nations Framework Convention on Climate Change adopted in 1992[7] and a series of negotiated or anticipated protocols. The Convention provides a long-term objective in Article 2:

> *"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."*

In 1997, the Kyoto Protocol to the FCCC was adopted. The Protocol includes quantitative commitments for the developed countries and designs mechanisms to help countries achieve their commitments in a cost-effective manner.[8] The Protocol sets an overall target of a reduction of 5.2% of global emissions by the year 2008-2012.

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7 The FCCC consists of 26 articles. It sets out a long-term goal, defines principles for developing the regime further, lists the policies and measures that countries should undertake, establishes a financial mechanism and outlines a reporting mechanism. The Convention entered into force in 1994 and has been ratified by 188 parties (including the EC). For a critical analysis of the content of the convention, see Bodansky, 1993.

8 For a critical analysis of the content of the Protocol see Oberthür and Ott, 1999; and Grubb et al., 1999.

This is very low in relation to the level of emission reductions that may be considered necessary in order to protect the earth from dangerous interference (e.g. Bolin, 1998). Of course, the determination of whether this is low or not depends on one's interpretation of dangerous emission levels.

The level at which the concentrations of greenhouse gases (GHGs) are eventually stabilized determines the overall level of global climate change. At the same time, the level of climate change and the severity of its impacts are highly uncertain, particularly at the regional level. Given the large uncertainties about the impacts of different stabilization levels it is necessary to address the question: do we need to set long-term stabilization targets in relation to GHG concentrations, and are concentrations of GHGs in the atmosphere the most appropriate indicator for setting long-term targets?

Climate change negotiations have so far focused almost exclusively on short-term issues related to GHG mitigation in the first commitment period (2008-2012) and the use of flexibility mechanisms in the Kyoto Protocol. However, action outlined in the Kyoto Protocol represents only an initial step towards achieving the overall objective of the FCCC. During a global dialogue project on Article 2 (Gupta et al., 2003), we discovered that most negotiators get so involved in the nitty-gritty details of negotiating short-term goals on the basis of narrow national interests, that they lose sight of the long-term objective and what it implies for national commitments. It is therefore necessary to look beyond shorter-term imperatives in order to address this objective and contribute towards a sound and equitable long-term solution to the challenge of climate change.

At the same time, the debate on ratification and entry into force of the Kyoto Protocol has been marked by calls to broaden the ambit of the Protocol by including developing country GHG mitigation commitments (e.g. Clinton, 1997). These demands have been countered by developing countries by references to their low cumulative and current per capita GHG emissions, low per capita incomes, low GHG intensity of GDP at purchasing power parity, and high vulnerability and poor coping capacity to climate change impacts (e.g. Gupta, 2001). There is an increasing awareness amongst developing countries of the implications of climate change and they demand that international climate policy making should not only deal with mitigation but also the issue of adaptation. There is a strong need for dialogue amongst policymakers and stakeholders about acceptable and unacceptable climate change impacts, about fair ways of dealing with the unequal distribution of impacts, and about options for a fair distribution of emission control and adaptation costs.

The level of climate change impacts is related to both the overall magnitude of the change, the rate at which it occurs, and the ability of the natural and human systems to tolerate or adapt to the change. Not all systems are equally vulnerable to climate change: some systems are likely to adapt more easily than others (See IPCC WG2, 2001). Human systems may adapt more easily than natural systems, while developed countries generally have more adaptive capabilities than developing countries. In assessing dangerous levels of climate change, adaptation options and capabilities need to be taken into account. This raises questions about how to evaluate different types of impacts and how to deal with regional and social differences in impacts. This also raises questions about critical impacts (impacts that should guide actions) and intergenerational solidarity (i.e. what time horizon should be taken when considering climate change impact risks).

The climate change problem basically constitutes a risk problem, where climate change impact risks need to be balanced against the risk of climate control policies. Acceptable levels of climate change will be defined in relation to the possible societal consequences of impacts, adaptation, and mitigation efforts. An assessment of non-dangerous climate change thus also entails an assessment of the implications of climate change control policies.

Defining "dangerous" has four critical dimensions:

- The inherent *uncertainty* in climate change science: scientific uncertainties make it very difficult to assess the likelihood of possible climate change events and thus to quantify the risks of climate change (IPCC WG2, 2001);
- The *scientific difficulty* for scientists to define what would be an acceptable level and time-frame for global concentrations of GHGs to be stabilized. This is because the evaluation of climate change risks is essentially a political issue and scientific opinions vary with regard to determining what can qualify, objectively speaking, as being "dangerous";
- The *political framing* of the problem where although climate change is seen as a global problem, the impacts and adaptation are seen as primarily local problems (Bodansky, 1993);
- The *scale mismatch* between the problem and decision-making: While the problem of climate change is a global problem, decision making at the international level is based on countries negotiating on the basis of what are perceived to be their national interests. Thus, countries may appear to take responsibility for the global nature of the problem, but when it comes down to specifics, countries take decisions on the basis of what is perceived as an unacceptable dangerous level for themselves.

In short, the climate change issue is characterised as an *unstructured problem* where both the values at stake, as well as the science are uncertain and subject to debate (Hisschemöller, 1993) and as a *wicked problem* since the costs of policies and impacts are asymmetrically distributed worldwide (e.g. Cunningham & Cunningham, 2002). This type of post-normal[9] science problem requires a methodological framework within which scientists, policy makers and other stakeholders can enter into a dialogue to assess what level of 'danger' (in terms of possible impacts) could be attached to different levels of climate change, what could be the implications of false policy responses (policies being either too loose or too stringent), and hence, what long-term concentration levels (or alternative policy indicators) may be considered acceptable and unacceptable, and on what grounds (criteria/values).

In determining what is dangerous it is important to realise two things:

- The climate system will only respond slowly to mitigation efforts: impacts of climate change will continue to manifest themselves well beyond the moment global GHG emissions are being reduced and even after GHG concentrations have actually been stabilized (see Figure 2.5 and Chapter 5). This means that short-term decisions about

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[9] Post-normal science calls for stakeholder participation where the science is uncertain, the stakes high and decisions imminent (Functovicz et al., 1996).

GHG emission control need to be evaluated from a long-term perspective, because they may foreclose long-term climate control options;

- Further, although the contribution of the Netherlands to addressing the problem in theory reduces the need to invest in adaptation within the Netherlands, these two should in fact be seen as separate issues. This is because of the inertia in the climatic system itself and because the Dutch efforts at reducing emissions are not necessarily accompanied by global efforts to reduce the emissions. This raises the question of what long-term climate change targets would imply for global emission control policies in the short to medium term (post 2012 policies).

In 1996, the Netherlands' government interpreted Article 2 of the FCCC as follows: The global average temperature should not rise above a maximum of 2 ºC of pre-industrial levels; in other words the rate of temperature change should be less than 0.1 ºC per decade, and sea-level rise should be limited to a maximum of 50 cm (VROM, 1996: 88-89). In preparing for the Kyoto negotiations, the EU Council too adopted a long-term climate policy goal to limit global warming to less than 2 ºC and a concentration level of 550 ppmv of CO_2 emissions.[10] Since then these policy goals have not been re-evaluated. This is because most of the policy attention since has focused on the negotiations of the Kyoto Protocol and preparations for implementations of the national commitments. However, with the upcoming discussions on post-Kyoto commitments and the increase in scientific insights into the risks of climate change and into options and cost of mitigation, a re-evaluation has become very policy relevant again. Such a re-evaluation is also valid in the light of the Netherlands presidency of the European Union (EU) in the second half of 2004. Thus, the main research question is: Do the climate policy goals need to be changed on the basis of the new science that is available and present valuation of the risks, policy efforts and socio-economic costs involved?

Clearly, this document is not unique in its focus on Article 2. The IPCC Fourth Assessment Report is now also looking at Article 2 but will not examine the values that underlie a determination of what is dangerous.[11] Bill Hare, the international climate policy director of Greenpeace International has just completed a book on the subject (Hare, 2003), but does not examine the values involved. The Pew Centre has set up a project on Post-Kyoto climate issues, based on a series of 3 international workshops on a set of academic papers, to be followed in 2004 by an international dialogue process.[12] Furthermore, the German Federal Environmental Agency (Umweltbundesamt) has published a study that dealt with, *inter alia*, the ethical aspects of articulating Article 2 (Ott et al., 2004) and is involved in organizing workshops and discussions on Article 2.[13]

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10 These two are not compatible goals and possibly reflects a compromise between those who wanted the tougher target of 2˚ C (equivalent to a 450 ppmv CO_2 emissions and 550 ppm CO_2 eq., and those who wanted a weaker target).

11 At the last meeting at Potsdam of the IPCC Assessment Report 4 it was decided that issues relating to article 2 would be a cross-sectoral element for all IPCC documents. See also Patwardhan et al. (2003) and Izrael (2002).

12 See the Pew Centre website : http://www.pewclimate.org.

13 See http://www.fiacc.net.

1.3 Objectives and research questions

The **objectives** of this report are to:

- Provide support to the evaluation and re-definition of the long-term climate policy goals of the Netherlands;
- Provide an overview of available science that meets the needs of the stakeholders in order to determine a dangerous level of climate change;
- Evaluate the appropriateness of the indicators selected and possible alternatives from both societal, political and technical points of view;
- Explore views and values of policy makers and stakeholders about acceptable climate change risks;
- Assess the risks and costs associated with different long-term climate policy targets (in terms of avoiding unacceptable risk levels and societal consequences);
- Evaluate the short-term implications of alternative long-term climate targets; and
- Thereby both contribute to the way the Netherlands prepares for the international negotiations on the issue; and to the anticipated global and national dialogues on Article 2.

The project focuses on the following specific **substantive questions**:

- How can Article 2 of the FCCC be elaborated into quantitative and qualitative indicators for climate change control? What operational criteria could be developed to indicate dangerous and non-dangerous levels of anthropogenic interference with the climate system? What indicators can be selected that are both politically relevant and publicly comprehensible and appealing, and can be scientifically substantiated (attributable to climate change, reliable/valid, measurable, predictable)? How can different indicators be aggregated?;
- What are the options for adaptation to avoid exceeding thresholds levels? What level of adaptation is feasible and acceptable?;
- How can the indicator levels be related to the possible scenarios? How are the indicator levels and the risks of exceeding critical levels related to levels of climate change? How can the levels of climate change be related to long-term goals for stabilization of GHG concentrations? How do these long-term concentration levels relate to GHG emission levels on the long term and the short-term? What would be the implications of limiting the risks of exceeding long-term indicators thresholds levels for global emission control on the short- to medium term (the post Kyoto period)?;
- What are the options and costs of meeting long-term stabilization targets? How are its feasibility and costs related to socio-economic and technological developments, social and institutional barriers, and the timing of mitigation efforts? How can risks of high future policy adjustment costs be limited (e.g. hedging)?;
- How can we deal with the unequal distribution of climate impacts and mitigation capabilities? What can be the role of supporting adaptation and/or providing compensation? How can mitigation costs be (e)valuated against adaptation costs/climate impacts?;
- What is the value of climate indicators and long-term climate targets for developing an effective international climate change regime and rallying societal support for dealing with climate change?

Procedural questions include:

- What do participants understand as key issues in Article 2?;
- What are the key knowledge gaps that need to be addressed?;
- Do participants believe that a discussion of Article 2 is critical for the future development of the climate change regime?;
- On the basis of what values and principles do participants define dangerous threshold levels for the various risk indicators? What are the arguments used by stakeholders to define dangerous levels? What are the common interests behind the different positions if any?;
- Do participants understand and accept the positions of others? What are the main points of conflict in the dialogues? What is the nature of disagreement: is it based on different reality claims, value claims and/or interests?;
- Is there social learning: do the participants get a better understanding of the positions of others? Does the dialogue change their views? Does the dialogue result in a convergence in views regarding facts, values or policy strategies (how to deal with Article 2)?;
- What is the role of experts? Does the dialogue in the community of climate change experts result in stronger common understandings of Article 2 amongst stakeholders or does it hinder this?

The **strategic importance** of this project lies in the fact that it focuses on:

- Article 2, the corner stone of the Climate Change Convention;
- The gap between science and policy and the need for a new form of science-policy interface;
- Communicating IPCC science to stakeholders in understandable language;
- Developing a methodology for understanding how 'dangerous' should be evaluated;
- Engaging actively in a discussion of facts and values in order to determine what is 'dangerous' climate change;
- Communicating the results back to IPCC through standard channels of communication;
- Supporting the preparations of the Netherlands government for the international negotiations. Negotiations on Post-Kyoto climate policies within the framework of the EU and the UNFCCC.

1.4 Theoretical framework: an exploration of indicators

An indicator is information – usually quantitative – pointing to a matter (state or development) of some significance (Spreng & Wils, 2000: 4). It describes a system or process such that it has significance beyond the face value of its components. It aims to communicate information on the system or process (UNESCO, 2003: 33). An aspect of an indicator is that it is measurable – either quantitative or qualitative – over time and/or space. This aspect enables various forms of comparison (Astleithner et al., 2004: 9).

The goal of climate indicators is to support the development and evaluation of climate policies. In general, indicators for sustainable development can provide the necessary guidance for policy makers in a number of ways:

- They can translate physical and social science knowledge into manageable units of information that can facilitate the decision-making process;
- They can help to measure and calibrate progress towards sustainable development goals;
- They can provide an early warning, sounding the alarm in time to prevent economic, social and environmental damage, and;
- They are also important tools to communicate ideas, thoughts and values.[14]

Indicators can be (Spreng & Wils, 2000):

- Technical indicators: quantifiable indicators, applied by engineers with regard to initially all kinds of properties of any kind of equipment, but later also to larger and more complex technical systems;
- Social indicators: indicators aimed at measuring the quality of life through statistical information (objective social indicators) and by leaving the choices to individuals (subjective social indicators);
- Environmental indicators: indicators that measure the natural state and/or the way human influences affect this state;
- Economic indicators: indicators that are used to measure the present state of the market or of companies (performance indicators) or to indicate a future direction (leading indicators); a distinction can be made between macro- and micro-economic indicators;
- Sustainability indicators: indicators that have their roots in the previously mentioned indicators and that may serve to monitor and communicate chances for and threats to sustainable development.

The main functions of indicators are simplification, quantification, communication and ordering. Indicators can relate and integrate information and allow comparison of different regions and different aspects (UNESCO, 2003: 34). Based on the functions that indicators perform, one can make the following distinctions:

- Static indicators provide information on the (changes in the) state of geophysical systems and ecosystems; their function is to point out changes in these systems and the chances that these system changes occur, thereby communicating information of the total system to policy-makers and the public;
- Effects indicators provide information on the (changes in risks of) (negative) impacts on natural and human systems due to climate change. Their function is to provide the basis for the valuation of impacts of climate change by measuring or estimating (changes in) effects and risks of climate change for the setting of set policy targets;
- Policy indicators serve to provide information on policy targets and the current state of affairs in relation to those targets (to what extent has the target been achieved?). Their function is to provide guidance for action and measuring or estimating policy effectiveness.

In applying indicators to climate change O'Neill and Oppenheimer (2002) identify as key indicators certain climate impacts, such as large-scale eradication of coral reef sys-

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[14] http://www.un.org/esa/sustdev/natlinfo/indicators/indisd/indisd-mg2001.pdf.

tems, disintegration of the West Antarctic Ice Sheet and the weakening or shutdown of the large-scale circulation of the oceans.

In general, four approaches on how indicators can be developed can be discerned:

- The bottom-up approach where the logic goes from data to parameters to indicators;
- The top-down approach, which follows the logic down from vision to themes to actions to indicators;
- The systems approach, which bases indicators on a comprehensive analysis of system inflows and outputs; and
- The cause-effect approach (commonly known as the Pressure-State-Response (PSR) approach or the Driving force-Pressure–State-Impact-Resource (DPSIR) or the Driving Force-Pressure-State-Exposure-Effect-Action (DPSEEA)), which subscribes to the logic of indicators denoting various causes and effects. (UNESCO, 2003: 37).

This report uses a combination of the top-down and the bottom-up approaches. The bottom-up approaches were used by the scientists and the top-down approaches were used by the stakeholders.

Although indicators can be quite useful for aforementioned purposes, there are nevertheless limits to their usefulness (UNESCO, 2003):

- Spatial and temporal scale: Indicators may not be relevant for all spatial or geographical scales. It may not be possible or desirable to aggregate the data for smaller scales in such a way that it applies to a higher spatial level. Furthermore, whereas an indicator could be very appropriate on a regional or national level, it would sometimes make little sense to use this indicator at the global level, given the considerable differences between regions and countries. Conversely, an indicator related to a global state or development will not always be appropriate for smaller spatial scales. The foregoing raises the question of the optimal spatial scale of use for an indicator. The answer to this question depends on the information needed and, related to this, the purpose and function of the indicator. The chosen spatial scale inevitably influences the information presented by the indicator; choosing a higher spatial level will usually be accompanied with loss of detail;
- Indicators may also not be useful for all temporal scales. For example, deaths from heat waves will occur mainly in summer, but annual statistics on the number of victims do not necessarily show this. Similarly, water availability calculated on an annual basis does not show water shortages or floods. It would therefore make more sense if the data were gathered on a seasonal basis. The temporal scale of an indicator is also dependent on the chosen point in time and the period of data collection;
- Visual presentation: With the presentation of indicator information, there is always the risk of simplification at the cost of scientific robustness. Whereas the end-user of the indicator cannot always consume all the scientific information contained in the indicator, simplifying this information is sometimes necessary;
- Changes over time: If the information contained in the indicator is measured over time, it is possible for the indicator to point out certain trends. These measurements through time require that at least the data is collected in the same way and that the indicator remains the same. However, it is sometimes necessary to upgrade the indicator or the method of data collection in order to obtain the best available

information. This implies a choice between the best available information and the best results over a longer period of time;
- Misinformation and misinterpretation: Misinformation and misinterpretation are risks inherently connected to the use of indicators. Firstly, indicator development inevitably contains some subjective elements. In order to prevent misinformation, it is imperative that these subjective elements are identified and described. Secondly, indicators may cause confusion if it is unclear how they are defined. Therefore, they should be sufficiently precise.[15] Thirdly, there may be certain mathematical problems in the process of aggregating indicators. Lastly, the data used may be unreliable. This problem may root from either the data collection or the data processing;
- Data availability: The availability of proper data can seriously hamper or influence the choice of indicators and the information contained in the indicator. From a scientific point of view, it makes little sense to choose an indicator for which no or little information is available or can be obtained, regardless of the social relevance of such an indicator. If the data is not yet available, the information needs should give the signal that such data should be sought. If the data desired cannot be obtained, other indicators should be sought.

1.5 Methodological design

This section elaborates on the role of the project in a larger set of projects on interpreting 'dangerous' climate change and the methodological design adopted to deal with the problem.

1.5.1 The place of this project in the context of international projects

This project focuses on the Netherlands' interpretation of Article 2. It follows up on a larger international project that focused on how different parts of the world interpret Article 2. Both are part of a design of a programme on Article 2 called Helping Operationalise article Two (HOT). The aim of these projects is to understand how stakeholders and scientists define danger on the basis of national and regional dialogues; and then to proceed to international dialogues on the same subject. Through an iterative series of dialogues, we hope to create scientific and social understanding of the key issues in understanding when climate change becomes dangerous to society. The projects hope to both contribute to the development of methodologies on this issue as well as to a better articulation of Article 2. Figure 1.1 shows the role of the Dutch project (the national dialogue) in the international series of projects.

1.5.2 The methodological approach

There are two alternative designs for undertaking a science-policy discussion on Article 2. In the first design, one can move from an understanding of the position of the stakeholders on concentration levels and emissions, to the arguments underlying these positions and then to an understanding of the conflicting values.

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[15] To be more specific, there should be a mechanism for cross-referencing and validating them.

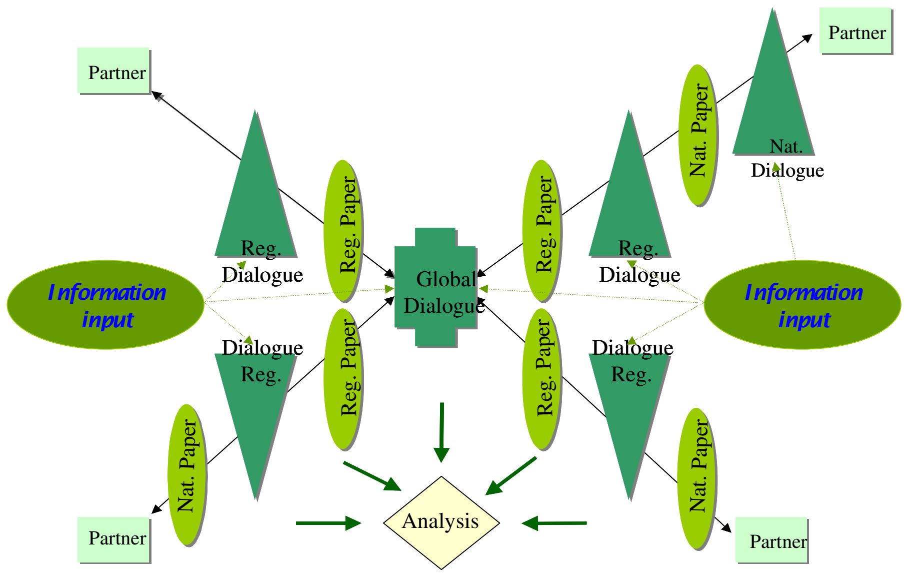

Figure 1.1 The place of this project in the HOT programme.

In the second design, one can ask stakeholders to identify indicators of climate change, define threshold levels for each indicator followed by a scientific back calculation to identify global concentration levels that correspond to those indicators (See Figure 1.2).

In the HOT programme as a whole and in this project, we have chosen the second design as the more appropriate approach for articulating what the Netherlands' position could be in relation to Article 2. There are two reasons for such an approach:

- First, this is easier to relate to for individual stakeholders, since the approach starts from climate impacts. Hence, climate change becomes a more concrete item in the discussion; and;
- Second, as long as discussions remain in the arena of generalities, it is often difficult for countries to actually understand how they themselves may be affected by climate impacts and how these impacts relate to concentration levels. This is not only true for developing countries, but also for the Netherlands, where we discovered that despite the enormous amount of information available, people were not really discussing the impacts. The underlying argument is that even if at a general level, Australia does not see the climate change issue as important, the Australian coral reefs will be among the first to be bleached; even if India does not see climate change as important, the Himalayas will be among the first to melt with devastating consequences for the country. Thus, through an understanding of the impacts in terms of indicators and thresholds, we may find that behind vastly differing positions lie common interests (cf. the negotiation theory of Fisher & Ury, 1981), and from the common interests we may be able to move towards common positions.

As mentioned earlier, in defining what is dangerous, the project team chose to move away from abstract terms such as concentration levels and average temperature to indicators of impacts.

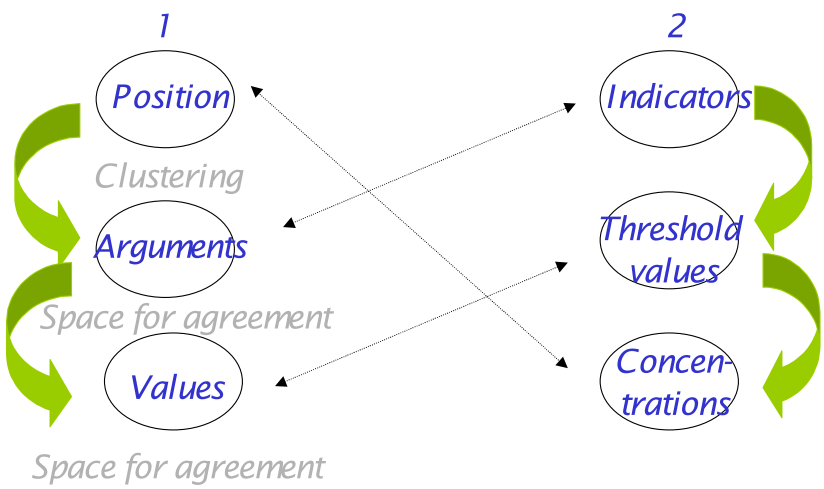

Figure 1.2 Approach for the workshops.

Chapter 5 explains how on the one hand we can trace the impacts of GHG emissions until the impacts, and also how we can back-calculate emission targets from the acceptable impact levels. Figure 1.3 shows how we can trace back from indicators the appropriate GHG concentration levels and GHG emissions.

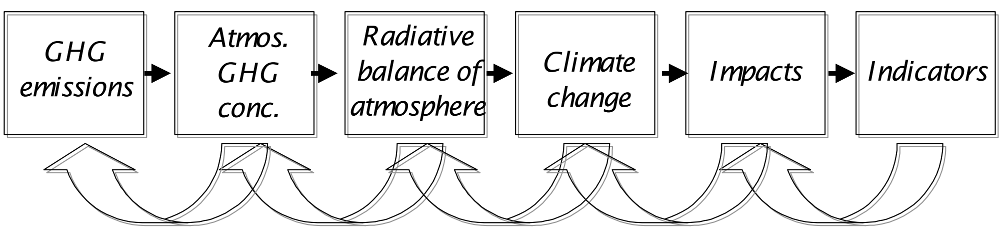

Figure 1.3 Calculating concentration levels and emission levels from impact indicators.

1.6 Step-by-step approach

The project team, consisting of 7 Dutch research institutes[16], adopted the following steps:

- Project plan: The project partners met to discuss the scope of the project, the methodology and the best way to undertake the assessment. This was done on the basis of: (a) their own scientific and professional knowledge; (b) the arguments underlying the

[16] These are: the Institute for Environmental Studies (IVM) of the Vrije Universiteit Amsterdam, the National Institute for Public Health and the Environment (RIVM), Wageningen University (WUR), the Royal Netherlands Meteorological Institute (KNMI), the Institute for Inland Water Management and Waste Water Treatment (RIZA), the National Institute for Coastal and Marine Management (RIKZ), the International Centre for Integrative Studies, Maastricht University (ICIS) and the UNESCO-IHE Institute for Water Education.

existing Netherlands' policy position; (c) existing projects undertaken in programmes funded in the Netherlands; (d) ongoing work within IPCC; and (e) other relevant projects including the HOT project on Article 2;

- Fact sheets on climate change: Each project partner prepared fact sheets on climate change leading to the articulation of relevant indicators of climate change for the Netherlands (see Appendix I); The fact sheets were subsequently elaborated into Chapters 2-6 of this report;
- Interviews with stakeholders: Simultaneously, the project team interviewed 30 stakeholders to identify the key perceptions of stakeholders in relation to Article 2 of the Convention (see Appendix II for a list of questions asked);
- First integration and preparation for the science-policy workshop: This was followed by the preparation for the first science-policy workshop and elaboration of the design of the workshop;
- Science-policy workshop 1: The first science-policy workshop was held on 26 March 2004 and included 34 participants. The workshop concluded with specific requests for information and ideas about how the indicators could be further developed (see Gupta et al., 2004 for a summary in Dutch and Chapter 7 for a summary in English);
- Second integration and preparation for the second science-policy workshop: The following step was to review the workshop results, assign tasks to project team members and to design the second workshop. The project team only undertook an assessment of the literature and did not conduct any new research;
- Presentation of the results to the Advisory Committee: The project subsequently presented the results of the project to the Advisory Committee on 27 May 2004 which coincided with a meeting of the Netherlands' Interdepartmental Task Force on Climate Change and took their advice on board;
- Presentation of results to IPCC: Youba Sokona of ENDA Tiers Monde, Senegal, presented the findings of the International and National HOT projects to the IPCC meeting in Buenos Aires in Argentina, and this is reported in the IPCC Expert Meeting on the Science to Address UNFCCC Article 2 including key vulnerabilities (Gupta & Sokona, 2004);
- Second science-policy workshop: This workshop was held on 7 June 2004 and led to a further discussion on the indicators and threshold levels (see Dalenoord et al., 2004 for a summary in Dutch and Chapter 7 for a summary in English);
- Final integration of results: The project team then extrapolated from the results of the workshop to develop a method for analysing the concept of dangerous and a conceptual framework. The final document was sent for review and revised accordingly.

The participatory integrated assessment methodology developed for this project is visualised below in Figure 1.4.

1.7 The structure of the report

The report is structured as follows. Chapter 2 provides a state of the art of the current information available on the problem of climate change, including a section on expected climatic changes in the Netherlands. Chapter 3 analyses the vulnerability of groups and countries, perceived risks and relevant indicators of dangerous climate change.

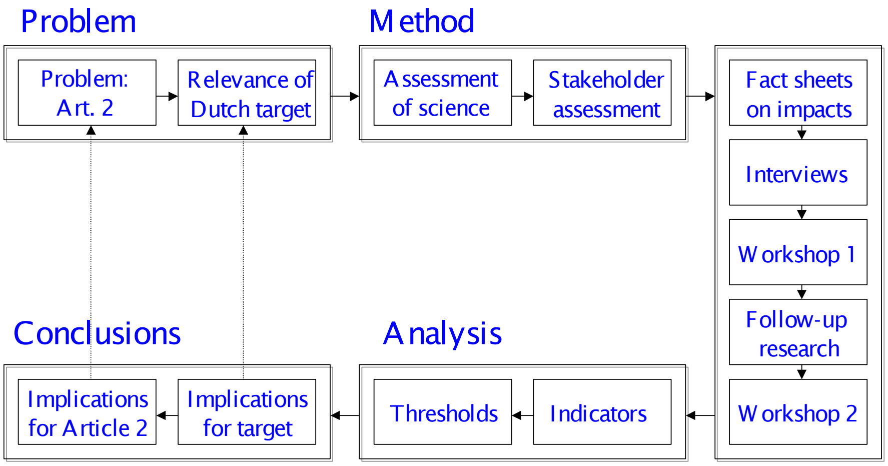

Figure 1.4 A diagrammatic representation of the project process.

Chapter 4 focuses on adaptation options. Chapter 5 then examines climate change thresholds and implications for GHG emissions. Chapter 6 then looks at the socio-economic implications of possible climate change policy targets. Chapter 7 then examines how stakeholders perceive the issue of long-term targets, both on the basis of past research, current interviews with stakeholders, and the results of the workshops. Chapter 8 then extra-polates from the research and workshops to make an internally consistent identification of the key indicators for the Netherlands, it examines alternative ways of classifying these indicators, uses a multi-criteria analytical process to prioritise the criteria, identifies the acceptable risks and unacceptable threshold levels, and then relates the information to GHG concentration levels. The chapter finally draws some conclusions.

After intensive debate within the project team, it was decided to provide the key conclusions of the report upfront in the report for easy access to the reader. A comprehensive summary of the report has also been placed prior to Chapter 1.

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2. Current scientific knowledge on human influences on climate

Coordinating lead author: Koos Verbeek

2.1 Introduction

In recent decades many disciplines have contributed greatly to increasing the insight in the mechanisms behind natural climate evolution and the human influence on climate. This chapter gives an overview of the current scientific level of understanding of climate change, from the viewpoint of the natural sciences, to provide a basis for the subsequent chapters that deal with impacts and potential measures against dangerous human interference with the climate system.

The science of climate change as a whole actually consists of many disciplines. An adequate understanding of the climate issue therefore requires extensive integration of a very wide range of insights. The Intergovernmental Panel on Climate Change (IPCC)[17], a scientific organisation founded by the United Nations, therefore periodically provides authoritative assessments of the complete scientific literature on climate change. This chapter is based on the latest IPCC Third Assessment Report (IPCC, WG1 2001). Additionally attention is paid to recent scientific developments, and typical aspects of climate change in the Netherlands.

This chapter first discusses the global temperature changes in the 20th century (Section 2.2) and the last millennium (Section 2.3), the observed changes in the global atmospheric composition (Section 2.4), the observed impacts of global warming (Section 2.5), expected climate change in the 21st century (Section 2.6) and beyond (Section 2.7), and expected changes in the Netherlands (Section 2.8).

2.2 Global temperature changes in the 20th century

The global climate has changed significantly in the course of the 20th century. An increasing body of observations gives a collective picture of a warming world and other associated changes in the climate system. Figure 2.1 illustrates the evolution of the global surface temperature in the last 140 years.

After about forty years of relative stability the temperature was seen to undergo three phases of warming (1910-1945), cooling (1945-1976) and then again warming (1976-2003).

On the timescales involved here, climate scientists identify three important factors (climate forcings) that explain this evolution.

- Large volcanic eruptions lead to global cooling due to the masking effect of the dust particles;

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17 See www.ipcc.ch.

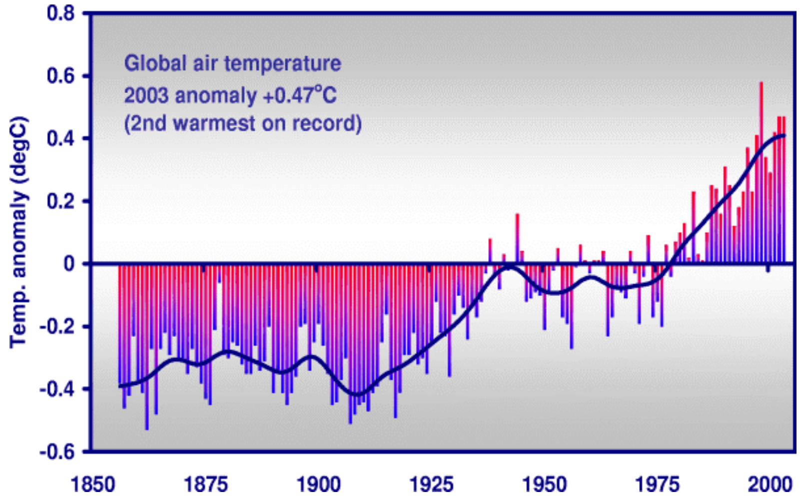

Figure 2.1 The global surface temperature in the period 1861-2003.

Source: Jones et al. (2003). Reproduced by kind permission of the Climatic Research Unit, University of East Anglia, Norwich, U.K. to whom any queries should be directed (cru@uea.ac.uk). Copyright: Climatic Research Unit.

- Variations in solar activity have a direct influence on the amount of energy the earth receives from the sun and thereby change the global temperatures;
- Changes in the atmospheric composition (GHGs and aerosols) influence the radiation budgets, resulting in fluctuation of surface temperatures.

An increasing number of studies confirm that the three phases mentioned above can be explained quantitatively by taking these three factors into account. The general picture now is that the warming of 1910-1945 can be associated with an increase in solar activity in the absence of volcanic activity. The cooling of 1945-1976 is explained by a sequence of large volcanic eruptions, in a period of solar stability. The warming of 1976-2003, under the cooling influence of large volcanic eruptions and in a period of solar stability, primarily is to be associated with the steadily increasing enhanced greenhouse effect as a result of anthropogenic emissions.

In 2001, the IPCC concluded that the human influence on climate is likely to have caused most of the observed warming in the second half of the 20th century. The scientific basis for this conclusion has been strengthened since then by a number of studies that confirm the dominant anthropogenic component in the climate forcing (see Figure 2.2). The question whether human activities have a significant influence on climate no longer is a subject of scientific debate. The research now is focused on further deepening of the understanding of the underlying mechanisms and, on the basis of these insights, quantifying possible future developments and impacts, with regional differentiation.

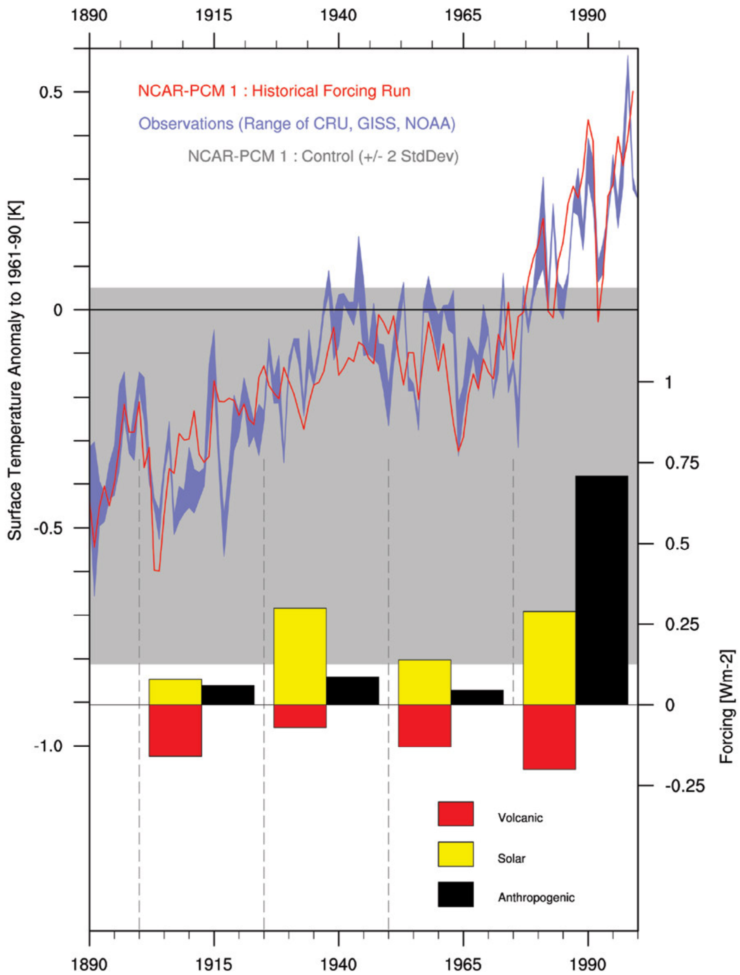

Figure 2.2 A modelled global surface temperature (red line) from 1890-2000 compared to observations (blue area, the width denotes the precision). The averaged volcanic, solar and anthropogenic climate forcings are indicated by the underlying histogram.

Source: Amman et al., 2004.

2.3 Global temperature changes in the last millennium

The significance of the warming in the 20th century can be seen in the context of a longer timeframe. The reconstruction of the global surface temperature before 1861 is hampered by the lack of instrumental observations. One therefore has to rely on indirect methods that deduce temperatures from tree ring records, coral data, ice cores, lake and ocean sediments and borehole measurements. These so called proxy indicators are not evenly distributed along the earth's surface. Notably Southern Hemisphere data are lacking. Figure 2.3 depicts four reconstructions for the Northern Hemisphere temperature. The spreading gives an indication as to the precision that can be attached to these studies. The black line, by Mann et al. (1999), can be considered the most sophisticated, as it is based on full hemisphere data and uses known spatial climate patterns to compensate for the sparseness of the datasets. The conclusion that can be drawn from this study is that the global climate has been very stable in the period 1000-1900, and that the warming in the second half of the 20th century is exceptional. In combination with the reasoning in the previous section this leads to the conclusion that human activities as from 1950 are increasing the global temperatures to levels that are unprecedented in the last millennium.

The Mann series has been criticised by Esper et al (2002) and others (see Esper paper), because of the handling of the tree ring data, possibly leading to an underestimation of natural temperature variability thereby underestimating the Medieval Warm Period. The Esper's series, which is consistent with the green Briffa (2000) reconstruction in Figure 2.3, indeed shows larger fluctuations. It is based on tree ring data only and consequently is restricted to extra-tropics (there are no tropical tree ring data available). One could argue that this leads to an exaggeration of variability because the tropics tend to exhibit much less variability than the higher latitudes. The Mann series also has been criticised by McIntryre and McKitrick (2003). They claim Mann has made significant errors in the data handling that are amplified by his statistical methods. Their reconstruction, exhibiting a very warm medieval period, is very different from the other scientific reconstructions and is in disagreement with historical sources (see editorial comment in EOS 2003).

Climate reconstruction is an active field in climate research. The forthcoming years will undoubtedly yield more details about the past climate. However, it is unlikely that the general picture of the exceptional, rapid warming in the second half of the 20th century will be adjusted.

2.4 Observed changes in the global atmospheric composition

The present global warming thus primarily is associated with the human influence on the atmospheric composition. Human activities have increased the atmospheric concentrations of GHGs and aerosols since the pre-industrial era. The atmospheric concentrations of key anthropogenic GHGs (i.e. carbon dioxide, methane, nitrous oxide and tropospheric ozone) reached their highest recorded levels in the 1990s, primarily due to the combustion of fossil fuels, agriculture, and land-use changes.

At present the warming effect of carbon dioxide is about as large as the effect of the other GHGs combined. When judging the effect over longer periods, the average lifetime, which is very different amongst these gases, must be taken into account. In that respect carbon dioxide also stands out in that it has a very long lifetime (many decades to centuries). Besides through these gases, human activity influences climate via the emission of dust particles and small droplets (aerosols).

The warming effect from anthropogenic GHGs is positive with a small uncertainty range. That from the direct aerosol effects is negative and smaller. The cooling effect of aerosols through their influence on cloud formation (the so called indirect aerosol effect) might be large but is as yet not well quantified. Airborne soot (black carbon stemming from the burning of biomass, diesel oil etc.) has a warming effect, both by absorbing radiation and by changing the albedo of snow.

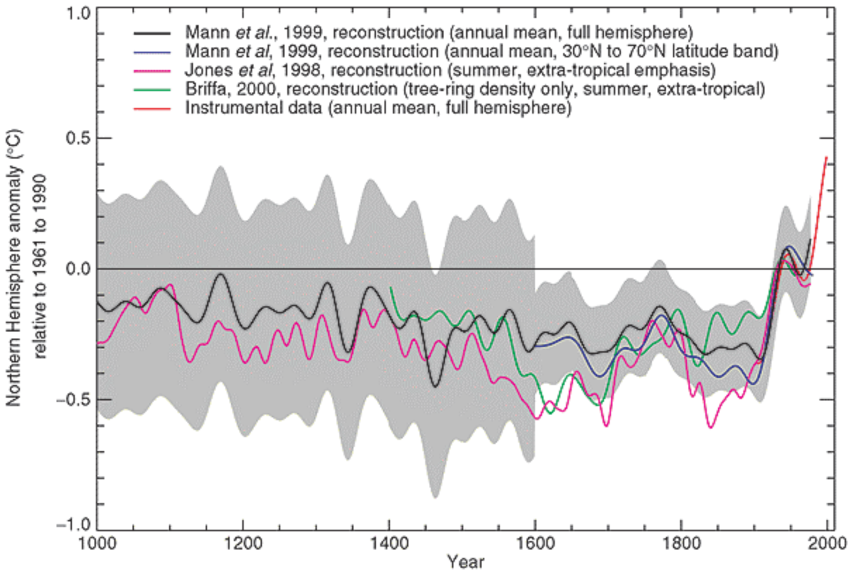

Figure 2.3 Four reconstructions of the Northern Hemisphere surface temperature in the last millennium.

Note: the grey area indicates the uncertainty in the most advanced series; black line by Mann et al. 1999.

Table 2.1 Observed changes in the atmospheric composition since the pre-industrial era (1000-1750).

Indicator	Observed Change
Carbon dioxide	280 parts-per-million (ppmv) from 1000-1750 to 368 ppmv in 2003 (+31%)
Methane	700 parts-per-billion (ppb) from 1000-1750 to 1750 ppb in 2000 (+150%)
Nitrous oxide	270 ppb from 1000-1750 to 316 ppb in 2000 (+17%)
Tropospheric ozone	Increase by 35% from 1750 to 2000 (varies with region)
HFC's, PFC's, SF6	Increased globally over the last 50 years

Source: IPCC WG 1, 2001.

The net effect of aerosols is a very important and as yet controversial topic in climate research. In the past the cooling effect of aerosols was inferred from "missing" global warming as predicted by climate models. Direct measurements that have come available since then seem to indicate that the cooling effect of aerosols (the "parasol effect") may be much larger (Anderson, 2003, Crutzen, 2003). If that is the case the future climate predictions (see 2.6) may change significantly because of the worldwide effort to cut aerosol emissions to improve air quality.

2.5 Observed impacts of global warming

Global warming has had a direct influence on weather patterns, as shown in Table 2.2.

Table 2.2 Observed changes in weather patterns in the 20th century.

Weather patterns	Observed changes
Global mean surface temperature	Increased by 0.6±0.2°C over the 20th century
Diurnal surface temperature range	Decreased during 1950-2000 over land: night time minimum temperatures increased at twice the rate of daytime maximum temperatures (likely)
Hot days	Increased (likely)
Cold days	Decreased for nearly all land areas (very likely)
Continental precipitation	Increased by 5-10% over the 20th century in the Northern Hemisphere (very likely), although decreased in some areas (like North and west Africa and parts of the Mediterranean)
Heavy precipitation events	Increased at mid- and high northern latitudes

Source: IPCC WG1, 2001.

These changes in weather patterns have had, in turn, biological, physical and economic impacts, as summarized in Table 2.3.

When judging the risks of further climate change, as is the subject of this assessment, insight in these observed impacts is necessary (See Chapter 3). That is to say, the impacts often are of more direct relevance than the temperature rise itself. Besides, from a scientific point of view, this kind of information is very relevant because it confirms the global warming that is deduced from temperature measurements. Basically all indicators, including the above-mentioned effects on weather systems, consistently point at a significant warming in the last decades.

2.6 Climate change in the 21st century

Scientific statements about future climate change are hampered by two different kinds of uncertainties that happen to be of the same magnitude. First there is the large uncertainty associated with the computer models that necessarily are involved, as no experiments are possible. It is impossible to judge the accuracy of a future climate simulation of a certain model on the basis of first principles. The scientific community therefore estimates the accuracy through the spreading in different model results. A central concept in this respect is climate sensitivity, that is, the ultimate rise in global temperature given a doubling of the pre-industrial level of carbon dioxide concentration. Current estimates of climate sensitivity range widely, between 1.7 and 4.2 ºC.

Another limitation is associated with the future emissions of GHGs. This heavily depends on future socio-economic and technological developments that of course cannot be forecasted with great accuracy.

One therefore has to resort to scenarios that sketch plausible lines along which the world may develop. For this reason one speaks of climate projections rather than forecasts.

The IPCC has developed six illustrative emissions scenarios (IPCC, 2000) that each has a certain character, on the basis of four storylines (see). In this section we will describe possible future developments of the global climate on the basis of these scenarios.

Table 2.3 20th century changes in biological, physical and economic systems, related to global warming.

Indicators	Observed impacts
Global mean sea level	Increased by 10-20 cm
Duration of ice cover of rivers and lakes	Decreased by about two weeks in Northern Hemisphere mid- and high latitudes (very likely)
Arctic sea-ice extend and thickness	Thinned by 40% in recent decades in late summer to early autumn (likely) and decreased in extent by 10-15% since the 1950s in spring and summer
Non-polar glaciers	Widespread retreat
Snow cover	Decreased in area by 10% since adequate observations are available (1960) (very likely)
Permafrost	Thawed, warmed, and degraded in parts of the polar, sub-polar, and mountainous regions.
El Niño events	Became more frequent, persistent, and intense during the last 20 to 30 years compared to the previous 100 years.
Growing season	Lengthened by about one to two weeks during the last 40 years in the Northern Hemisphere, especially at higher latitudes
Plant and animal ranges	Shifted pole wards and upwards in elevation for plants, insects, birds, and fish.
Breeding, flowering, and migration	Earlier plant flowering, earlier bird arrival, earlier dates of breeding season, and earlier emergence of insects in the Northern Hemisphere
Coral reef bleaching	Increased frequency, especially during El Niño events
Weather-related economic losses	Global inflation-adjusted losses rose an order of magnitude over the last 40 years. Part of this is linked to socio-economic factors and part is linked to climate change.

Source: IPCC, 2001.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol. Carbon dioxide concentrations, globally averaged surface temperature, and sea level are projected to increase under all IPCC emissions scenarios during the 21st century.

For the six illustrative SRES emissions scenarios, the projected concentration of carbon dioxide in the year 2100 ranges from 540 to 970 ppmv, compared to about 280 ppmv in the pre-industrial era and about 368 ppmv in the year 2000. The different socio-economic assumptions (demographic, social, economic, and technological) result in the different levels of future GHGs and aerosols. Further uncertainties, especially regarding the persistence of the present removal processes (carbon sinks) and the magnitude of the climate feedback on the terrestrial biosphere, cause a variation of about -10 to +30% in the year 2100 concentration, around each scenario.

Table 2.4 The storylines in IPCC's Special Report on Emissions Scenarios (SRES).

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).
The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Therefore, the total range is 490 to 1,260 ppmv (75 to 350% above the year 1750 (pre-industrial) concentration). Concentrations of the primary non-CO_2 GHGs by the year 2100 are projected to vary considerably across the six illustrative SRES scenarios.

Projections using the SRES emissions scenarios in a range of climate models result in an increase in globally averaged surface temperature of 1.4 to 5.8°C over the period 1990 to 2100. This is about two to ten times larger than the central value of observed warming over the 20th century and the projected rate of warming is very likely to be without precedent during at least the last 10,000 years, based on paleoclimate data. Temperature increases are projected to be greater than those in IPCC's Second Assessment Report (IPCC WG1, 1996), which were about 1.0 to 3.5°C based on the IS92 scenarios that IPCC used then. The higher projected temperatures and the wider range are due primarily to lower projected sulphur dioxide (SO_2) emissions in the SRES scenarios relative to the IS92 scenarios. For the periods 1990 to 2025 and 1990 to 2050, the projected increases are 0.4 to 1.1°C and 0.8 to 2.6°C, respectively. By the year 2100, the range in the surface temperature response across different climate models for the same emissions scenario is comparable to the range across different SRES emissions scenarios for a single climate model.

Figure 2.4 Future carbon dioxide and sulphur dioxide emissions for the six illustrative IPCC scenarios and their impacts on temperature and sea level.

Source: IPCC WG1, 2001.

Nearly all land areas will very likely warm more than these global averages, particularly those at northern high latitudes in winter.

Globally averaged annual precipitation is projected to increase during the 21st century, though at regional scales both increases and decreases are projected of typically 5 to 20%. It is likely that precipitation will increase over high-latitude regions in both summer and winter. Increases are also projected over northern mid-latitudes, tropical Africa, and Antarctica in winter, and in southern and eastern Asia in summer. Australia, Central America, and southern Africa show consistent decreases in winter rainfall. Larger year-to-year variations in precipitation are very likely over most areas where an increase in mean precipitation is projected.

Glaciers are projected to continue their widespread retreat during the 21st century. Northern Hemisphere snow cover, permafrost, and sea-ice extent are projected to decrease further. The Antarctic ice sheet is likely to gain mass, while the Greenland ice sheet is likely to lose mass.

Global mean sea level is projected to rise by 0.09 to 0.88 m between the years 1990 and 2100, for the full range of SRES scenarios, but with significant regional variations. This rise is due primarily to thermal expansion of the oceans and melting of glaciers and ice caps. For the periods 1990 to 2025 and 1990 to 2050, the projected rises are 0.03 to 0.14 m and 0.05 to 0.32 m, respectively.

When judging the risks associated with climate change the associated increases in intensity and frequency of extreme climate events and their impacts, as summarized in Table 2.5, are of special importance.

Besides the gradual changes there is a chance the global climate could change abruptly as a consequence of global warming. The weakening or shut down of the North Atlantic Gulf Stream, as a result of the release of (sweet) melting water of polar ice and increased rainfall at higher latitudes, would result in a sudden drop in Western European temperatures. Another example is the breaking and consequently the melting of the West Antarctic Ice Sheet, which would result in an extra sea-level rise of one meter per century for many centuries, thus leading to worldwide disaster. The chance that these events will occur in the 21st century is judged very low and is not taken into account in the IPCC climate projections.

2.7 Climate change beyond the 21st century

Inertia is a widespread inherent characteristic of the climate system. Thus some impacts of anthropogenic climate change may be slow to become apparent, and some could be irreversible if climate change is not limited in both rate and magnitude before associated threshold values, which may be poorly known, are crossed.

Stabilization of CO_2 emissions at near-current levels will not lead to stabilization of CO_2 atmospheric concentration, whereas stabilization of emissions of shorter-lived GHGs such as methane leads, within decades, to stabilization of their atmospheric concentrations. Stabilization of CO_2 concentrations at any level requires eventual reduction of global CO_2 net emissions to a small fraction of the current emission level. The lower the chosen level for stabilization, the sooner the decline in global net CO_2 emissions needs to begin.

After stabilization of the atmospheric concentration of CO_2 and other GHGs, the surface air temperature is projected to continue to rise by a few tenths of a degree per century for a century or more, while sea level is projected to continue to rise for many centuries (see Figure 2.5). The slow transport of heat into the oceans and slow response of ice sheets means that long periods are required to reach a new climate system equilibrium.

Some changes in the climate system, plausible beyond the 21st century, would be effectively irreversible. For example, major melting of the ice sheets and fundamental changes in the ocean circulation pattern cannot be reversed over a period of many human generations. The threshold for fundamental changes in the ocean circulation may be reached at a lower degree of warming if the warming is rapid rather than gradual.

2.8 The European and the Netherlands' climate in the 21st century

The average temperature in Europe will probably rise slightly more than the global average. In Scandinavian countries the temperature in winter probably will rise much more than the global average. In Southern Europe it seems that notably summer temperatures will rise. The future developments with regard to precipitation are inherently uncertain. There is reasonable scientific agreement that winter precipitation in Northern Europe will increase by 5-20%, particularly in Scandinavia, but also at lower latitudes. The changes in summer precipitation are highly uncertain. In Southern Europe it could decrease by more than 20%.

An increase in heavy precipitation is expected, on both daily and yearly timescales. Higher temperatures enhance evaporation.

Table 2.5 Examples of climate variability and extreme climate events and examples of their impacts.

Projected Changes during the 21st Century in Extreme Climate Phenomena and their Likelihood	Representative Examples of Projected Impacts (all high confidence of occurrence in some areas)
Higher maximum temperatures, more hot days and heat waves over nearly all land areas (very likely)	Increased incidence of death and serious illness in older age groups and urban poor. Increased heat stress in livestock and wildlife. Shift in tourist destinations. Increased risk of damage to a number of crops. Increased electric cooling demand and reduced energy supply reliability.
Higher (increasing) minimum temperatures, fewer cold days, frost days and cold waves over nearly all land areas (very likely)	Decreased cold-related human mortality. Decreased risk of damage to a number of crops, and increased risk to others. Extended range and activity of some pest and disease vectors. Reduced heating energy demand.
More intense precipitation events (very likely, over many areas)	Increased flood, landslide, avalanche, and mudslide damage. Increased soil erosion. Increased flood runoff could increase recharge of some floodplain aquifers. Increased pressure on government and private flood insurance systems and disaster relief.
Increased summer drying over most mid-latitude continental interiors and associated risk of drought (likely)	Decreased crop yields. Increased damage to building foundations caused by ground shrinkage. Decreased water resource quantity and quality. Increased risk of forest fire.
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (likely, over some areas)	Increased risks to human life, risk of infectious disease epidemics and many other risks. Increased coastal erosion and damage to coastal buildings and infrastructure. Increased damage to coastal ecosystems such as coral reefs and mangroves.
Intensified droughts and floods associated with El Niño events in many different regions (likely) (see also under droughts and intense precipitation events)	Decreased agricultural and rangeland productivity in drought- and flood-prone regions. Decreased hydropower potential in drought-prone regions.
Increased Asian summer monsoon precipitation variability (likely)	Increase in flood and drought magnitude and damages in temperate and tropical Asia.
Increased intensity of mid-latitude storms (little agreement between current models)	Increased risks to human life and health. Increased property and infrastructure losses. Increased damage to coastal ecosystems.

Source: IPCC WG1, 2001.

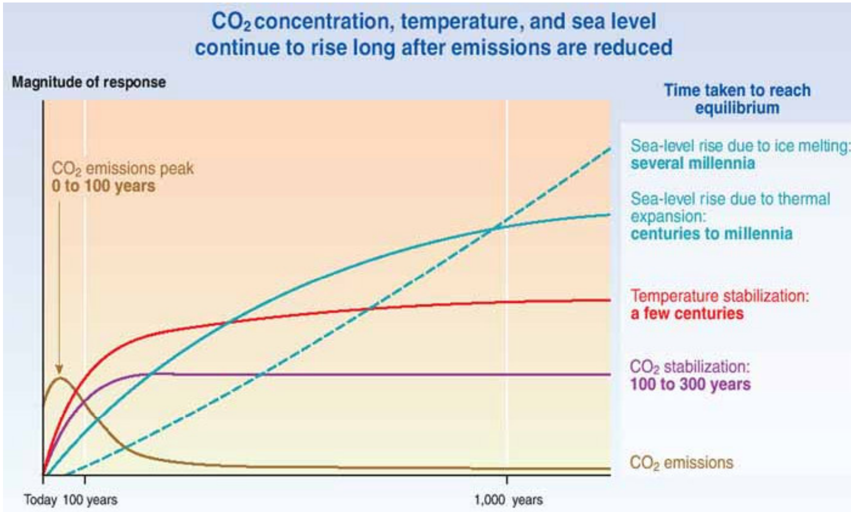

Figure 2.5 Projections of impacts.

Note: Figure 2.5 shows that after CO_2 emissions are reduced and atmospheric concentrations stabilize, surface air temperature continues to rise slowly for a century or more. Thermal expansion of the ocean continues long after carbon dioxide emissions have been reduced, and melting of ice sheets continues to contribute to sea-level rise for many centuries. This figure is a generic illustration for stabilization at any level between 450 and 1,000 ppmv, and therefore has no units on the response axis. Responses to stabilization trajectories in this range show broadly similar time courses, but the impacts become progressively larger at higher concentrations of carbon dioxide.
Source: IPCC, 2001.

In contrast with the winter period, in the summer evaporation will increase more than precipitation, leading to greater chances of summer drought, particularly in Southern Europe.

In the summer of 2003 central Europe experienced a very extreme heat wave that broke all records. In a recent paper Schär et al. (2004) suggest the extremity of this heat wave defies statistics and can be explained only by assuming that the chances on such an event have already shifted significantly because of global warming. A detailed analysis that was confirmed by several research groups has shown that the heat was greatly enhanced by a large-scale drought that built up in the course of the already hot summer. At some point the water in the soil ran out, stopping natural evaporation, thereby blocking the natural cooling effect associated with evaporation (c.f. sweating), and thus amplifying the heat to unprecedented levels. This case shows that unforeseen effects can amplify the impact of global warming on extreme events. It is yet too early to quantify these shifts in statistics. IPCC's Fourth Assessment Report to appear in 2007 will probably contain more information on this.

The Royal Netherlands Meteorological Institute (KNMI) has developed a number of scenarios for the Netherlands (see Table 2.6), taking the IPCC-temperature projections as a starting point.[18]

Table 2.6 KNMI Climate scenarios for the Netherlands in 2100.

Temperature	+1ºC	+2ºC	+4 to +6ºC
Mean summer precipitation	+1%	+2%	+4%
Summer evaporation	+4%	+8%	+16%
Mean winter precipitation	+6%	+12%	+25%
Intensity in winter precipitation	+10%	+20%	+40%
Frequency of intense winter precipitation	2 times as high	4 times as high	10 times as high
Sea-level rise (both anthropogenic and natural	+20 cm	+60 cm	+110 cm

Note: 1990 is the reference year for this table.

It is clear that for the Netherlands, like in many other low lying coastal areas in the world, climate change will pose its problems primarily through its effect on water management. For this reason the Netherlands government already takes far-reaching measurements to cope with these present and future impacts.

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3. Vulnerability, risks and relevant indicators of dangerous climate change risks

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3.1 Introduction

The previous chapters elaborated on the possible human influence on the climate system and actions taken by IPCC in order to mitigate the effects of climate change. Additionally, the character of indicators that play an important role in the (international) policy making process was explained.

This chapter focuses on a more specific description of relevant indicators used in the climate change impact debate. An important aspect is that the climate change indicators will be related to vulnerable sectors where impacts of climate change will lead to higher (and even dangerous) risks for society.

During the process of stakeholder involvement, the following sectors and items were considered relevant for the climate change debate in the Netherlands: health, ecosystems, food supply, economy and water management with special attention to impacts on the coastal zone.

In this chapter, the potential impacts of climate change are examined. It subsequently discusses the impacts of climate change on ecosystems (Section 3.2), food production (Section 3.3), water management (Section 3.4), health (Section 3.5), tourism (Section 3.6) and coastal zone management (Section 3.7). It discusses the impacts at two scales, (i) the international (global) scale, and (ii) the European and national scale. The assessments are based upon a review of recent scientific literature.

3.2 Ecosystems and ecosystem services

3.2.1 International level

In this section, the observed and potential impacts of climate change on ecosystems at the global scale are analysed. These impacts are likely to be manifold and diverse, due to individualistic responses of each species to changing temperature and precipitation patterns. The observed and potential impacts described in this section are based upon our experience and a concise literature review, in particular Houghton et al. (2001), McCarthy et al. (2001) and Metz et al. (2001).

The main issues relevant for this assessment and their relationship are shown in Figure 3.1. The impacts of climate change on ecosystems take place across different spatial scales. Hence, it is difficult to distinguish international and European scale in the assessment. We therefore distinguish in this report the global impacts on ecosystems, and the ecological implications at the European and national scale. The global impacts are described below, the European and national impacts are analysed in the next section.

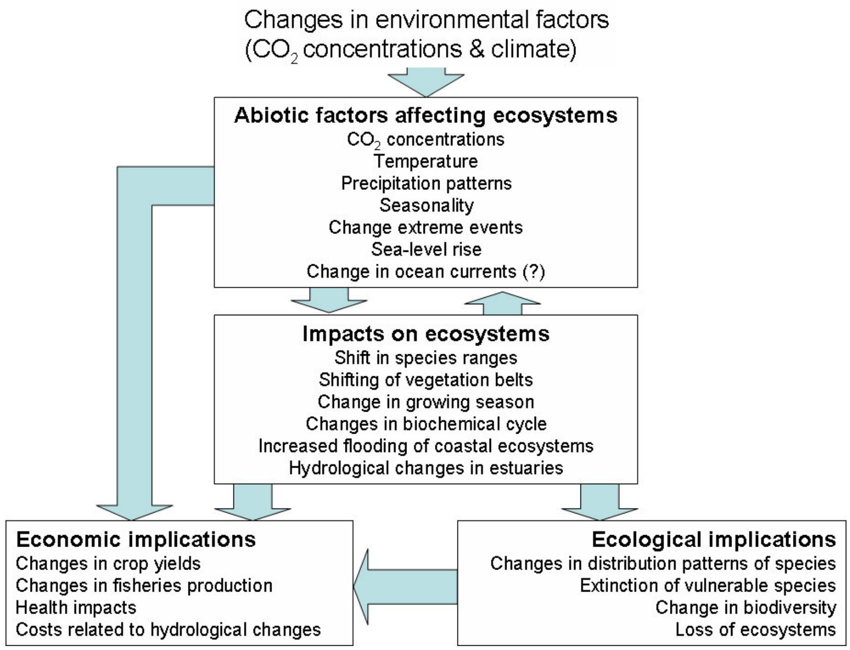


Figure 3.1 Impacts of climate change on ecosystems.

Change in growing season

The growing season is the period with suitable growing conditions for plant growth, related to, in particular, temperature and rainfall patterns. It is limited by dry and cold seasons. Warming will relieve the cold constraints and over the last decades increases over the growing season have been observed in all temperate and boreal zones. Many plant species immediately respond to this by adjusting the timing of their leafing and flowering. Such phenological responses are nowadays well-documented and show that the adaptive capacity of many plants to such climate change is immediate. However, these plant responses have consequences for other species in an ecosystem. The shifting timing could jeopardize long-established dependencies in many ecosystems, especially for those ecosystems with migratory species (e.g. Both & Visser, 2001)

An additional consequence of the lengthening of the growing season is that the pollen season will start earlier and will be longer. Here, there will be a synergetic effect with N-deposition. Such N will stimulate plant growth, part of which will be portioned into extra pollen production. The longer and higher pollen loads will be detrimental for people with hay-fever problems.

Shifts in species ranges

One of the factors that determine the distribution of species is climate. This is more apparent for plant than for animal species. There are now several techniques that link species ranges and abundances to patterns of environmental factors. Using these techniques to determine the change in species' ranges under climate change, show strong individualistic responses of each species. Under warming most species ranges shift northwards, but in Europe with its east-west continental gradient, many species also shift in eastern direction. The species that will adequately shift under rapid climate change are those with few environmental constraints, fast dispersal mechanisms and easy colonizers. Most trivial weed and pest species belong to this group. Species with specific environmental needs (i.e. specialists), long life times and slow dispersal mechanisms are at a major disadvantage. Under climate change biodiversity will decline and species composition in many landscapes will be less heterogeneous and consist of more weedy species. The risk of extinction for many species that are already vulnerable will thus increase. This has recently also been suggested by Bakkenes et al. (2002). These changes will lead to shifts in species composition and are likely to lead to an accelerated extinction of many of the red-list species.

Shifts in species ranges over the last decades due to the small warming of 0.6 °C have already been observed. For example, lichen flora over the Netherlands nowadays also include subtropical and even some tropical species. Higher plants and butterflies have also shown significant responses.

Shifting of vegetation belts

Global and regional vegetation patterns are strongly determined by climate. Locally, differences in soil, hydrology and land-use history become more dominant. These have been used since long to reconstruct historic climate on basis of plant remains (e.g. pollen analysis). Changes in climate will thus lead to shifts in vegetation patterns. For each degree warming, tree lines shift 300 km pole wards and about 15-20% of all terrestrial vegetation will change species composition. The outcomes of these shifts are not always detrimental. Some can be positive in certain aspects. For example, shifting tree lines leads to more forests and potentially more carbon stored. However, some of these shifting vegetation zones, such as nival, alpine and tundra zones, could well irreversibly disappear. This is, for example, already happening with the unique tropical alpine vegetation on Mount Kilimanjaro. Also, shifts in vegetation take time and vegetation belts that move out of their climatic equilibrium, are prone to rapid deterioration by disturbances like pests and fires.

It is nowadays relatively easy to depict shifting vegetation zones for different climate change scenarios. Robust models and indicators are available (cf. Leemans & Eickhout, 2003; Gitay et al., 2002; Malcolm & Markham; 2000; and Hare, 2003)

Changes in biochemical cycles

Temperature and moisture availability is an important factor in many physiological and ecological processes. Photosynthesis of plants has a temperature optimum. Decomposition processes accelerate exponentially with increases in temperature, provided that there is enough moisture. Enhanced CO_2 concentrations further tend to stimulate growth, but this is only a temporary effect that saturates rapidly. Several plant species tend to consume less water under such conditions. The importance of these positive and negative feedbacks can be assessed with models, and the potential consequence is large. The current understanding is that initially, more carbon will be stored with limited amounts of warming. This is a negative feedback on atmospheric CO_2 concentrations. However, some models show that, at temperature increases larger than 3 ^{o}C, the biosphere could well become a source, instead of the current sink, related to the release of greenhouse gases from boreal zones currently under permafrost.

Increased flooding of coastal ecosystems

Globally by the year 2080 about 20% of coastal wetlands could be lost due to sea-level rise. The impact of sea-level rise on coastal ecosystems will vary regionally and will depend on erosion processes from the sea and depositional processes from land. Particularly vulnerable are coral reefs, which may be seriously affected where sea surface temperatures would increase by more than 1^{o}C above the seasonal maximum. These systems are also affected by increasing CO_2 levels. Increased oceanic CO_2 concentrations affect the ability of the corals to form skeletons and grow.

Hydrological changes in estuaries

This broad term covers impacts, such as the increased eroding of beaches and coastal zones that are currently being eroded, as well as changes in river courses and groundwater levels as a consequences of sea-level rise (as further discussed in Section 3.7)

3.2.2 European and national level

In this section, we discuss the impacts of climate change on European and national ecosystems. We subsequently discuss (i) changes in distribution patterns of species; (ii) extinction of species not able to adapt; and (iii) changes in ecosystems.

Changes in distribution patterns of species

Changing temperature and rainfall conditions are likely to result in a change of the distribution of species. In general, as temperature increases, species ranges can be expected to migrate towards the pole and, in mountain ecosystems, towards higher altitudes. This may result in the loss of species that are not able to adjust their distribution, and the alteration of ecosystems, see below.

Extinction of species not able to adapt

In general, climate change will increase the risk of extinction of vulnerable species. This may be because the species are not able to adjust their geographic distribution, for instance because they live near the top of mountains, on low-lying islands, or in patchy habitats surrounded by agricultural or urban land. Another cause may be that changes in ecosystems, such as phenological changes or changes in species composition may affect certain species. This may occur, for example, if the timing of flowering of a plant no longer corresponds with the migration pattern of an insect required for its pollination. In general, species with the most limited climate ranges, and the most restricted habitat requirements are the most likely to be affected.

Changes in ecosystems

The changes in ecosystems may be brought about by a range of factors, including the changes in species distribution, changes in food chains, changes in biochemical cycles, etc. Changes in food chains may result from the increased or decreased access to prey species. For example, longer ice-free seasons in the artic will restrict the access of polar bears to seals and reduce their nutritional status and reproductive success. Enhanced bio-chemical cycles may affect the habitat of species. In addition, changes in rainfall patterns may disrupt whole ecosystems, in particular in cases where lower rainfall in systems already under water stress. These types of long term changes may also reduce the resilience of ecosystems to other pressures. For example, increased droughts may reduce the resilience of rangelands to high grazing pressure.

Because of their diversity and complexity, the overall impacts of climate change on eco-system are difficult to capture in a specific set of indicators. However, Figure 3.2 presents the potential impacts on a range of ecosystem types (including global impacts), based upon best current knowledge (Hare, 2003).

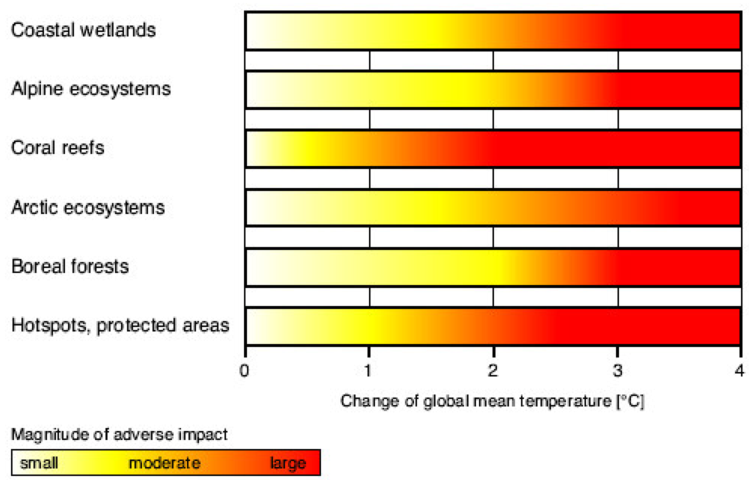


Figure 3.2 Visualization of climate change impacts on some ecosystem types.

Source: WBGU, 2003. Reproduced by kind permission of the WBGU. Copyright WBGU.

The risk of adverse impacts due to different climate-related parameters increases with the magnitude of climate change. Global mean temperature rise since 1861–1890 is used as proxy. The figure presents a global summary of expected adverse impacts upon some examples of global ecosystem types, in the form of a highly aggregated conceptualiza-tion. Regional impacts may be more or less severe than the global averages shown. The figure does not reflect a quantitative approach but a fuzzy assessment of risks, based on case studies and reviews. The assessment takes into account only the magnitude of climate change, not the rate of change (WBGU, 2003).

3.2.3 Uncertainties and research gaps

The uncertainties related to the impacts of climate change on ecosystems are manifold and significant. Uncertainties relate to what extend species and ecosystems will be able to adjust to changing climatic conditions – in a world with many other strong pressures on remaining ecosystems and species (deforestation, invasions of exotic species, pollution, land use conversion, overexploitation of certain species, etc.). It is the combined impacts of climate change and other disturbances that will determine the fate of biodiversity, at the national, European and international levels. Specific factors that contribute to the uncertainty include: (i) the impacts of multiple changes in the ecosystem on individual species (e.g. changes in temperature and rainfall combined with a change in the amount or timing of feed available); (ii) impacts of changes in oceanic currents on marine species including the whole food chain from plankton and algae up to top predators and whales; (iii) the possibility of species to adjust through migration or adaptation to a changing habitat.

3.3 Food supply

3.3.1 International level

This section briefly discusses the impacts of global climate change on global food production. The impacts of climate change on food production and agriculture depend on the vulnerability of regional agricultural systems, and the adaptive capacities of local and national populations and economies. Relevant factors in determining the response of agricultural systems to climate change include temperature, precipitation, CO_2 fertilization and socio-economic conditions such as market access, technology and the availability of resources needed for adaptation (IPCC, 2001). In the mid-latitudes, a moderate increase in temperature may raise crop production provided that water availability is not compromised. However, in the tropics, crops are often close to their thermal optimum, so that regional warming may instead result in reductions. Extreme weather events are likely to negatively influence crop production substantially, either directly or through increase of pests (WBGU, 2003). Below, we discuss the specific impacts on crop yields and fisheries yields.

Changes in crop yields

The impacts on crop yields are difficult to predict as they are strongly location specific, and as they are guided by different mechanisms that may counteract or reinforce each other. The IPCC Technical Paper on Climate Change and Biodiversity (Gitay et al., 2002) indicates that already overall net primary productivity of terrestrial vegetation is increasing leading to the accumulation of carbon in these ecosystems. As a result, agricultural productivity may also increase. In addition, increasing temperatures may lead to an expansion of the agricultural zones northwards towards the Tundra areas. However, reductions in rainfall in relatively dry areas (the Mid-western USA has been mentioned as a potential example), if effected, will lead to a loss of productivity in these zones. An increase of extreme events (drought, storms, frost) may also affect agricultural productivity.

Changes in fisheries production

A major factor determining the impact of climate change on fisheries production is the potential change in stratification in the oceans. Surface nutrient supply could be reduced if ocean stratification reduces the supply of major nutrients carried to the surface from the deep ocean. In regions depending upon this as the main nutrient source, stratification would reduce marine productivity. Temperature changes may affect the distribution of fish species, such as tuna and sockeye salmon. Moreover, changes in ocean currents, or increases in El Niño activity could have a major impact on regional fisheries - as in the case of Peruan fisheries in El Niño years.

Table 3.1 Global warming and impacts on food production in developing and industrialized countries.

GMT Increase (^{o}C)	Impacts Developing Countries	
1.0-1.7	Cereal yields decrease in most tropical and subtropical regions (* to **). Reduced frost damage to some arable crops (***). Increased heat damage to some arable crops and animal herds (***).	Cereal yields increase in many high- and mid-latitude regions (* to **). Reduced frost damage to some arable crops (***). Increased heat damage to some arable crops and animal herds (***).
1.4-3.2	Stronger decrease of cereal crops in the tropics and subtropics (* to **); mixed effects in high- and mid-latitude regions (* to **).	Mixed effects upon cereal yields in high- and mid-latitude regions (* to **).
1.5-2.0	Income of poor farmers in developing countries declines (* to **).	
1.6-2.6		Australian crop yields begin to decline after initial increase.
>2	Large drops in yield of maize and sugar-cane in small island developing states.	European crop production increases (except Portugal, Spain, Ukraine). US agriculture suffers losses after previous gains.
>2-2.5	Crop yield losses in developing countries.	
>3	Crop yield losses in developing countries. A group of 65 countries loges 16% of agricultural GDP; Africa and India lose, China gains.	
>2.0-6.4	General reduction in cereal yields in most mid-latitude regions (* to **). General increase in food prices (* to**)	General reduction in cereal yields in most mid-latitude regions (* to **). General increase in food prices (* to **).
>2.6	Asia: net losses in rice production begin	
>4.2		Entire areas in Australia out of production.

Note: The asterisks indicate confidence levels (where given in the literature):
*** high (67–95%), ** medium (33–67%), * low to medium (5–33%). GMT global mean temperature, pre-industrial level. Source: WBGU, 2003. Reproduced by kind permission of the WBGU.

As with the impacts on ecosystems, the impacts will be highly site-specific, and difficult to capture in a general set of indicators and threshold values. Moreover, as the impacts will differ locally, it is very difficult to define global thresholds. However, Table 3.1 presents a general overview of the potential impacts of climate change on global food production.

3.3.2 European and national levels

The considerable uncertainties in climate change make it difficult to pinpoint the impacts of climate change on European and national agriculture. However, some general observations can be made. In general, the major impacts relate to changes in rainfall, temperature and extreme events including floods.

Rainfall

Broadly speaking, the IPCC scenarios (IPCC, 2001) show a reduction of precipitation in the Southern half of Europe. The large majority of this area has a rain deficit throughout the year, and in particular during the growing season. Hence, for this part of the continent, a significant negative impact can be expected. This impact will be most severe in countries that have few opportunities to cope with increasing water deficits, such as Spain. For the wetter, Northern half of Europe, an increase in rainfall is expected, in particular at higher latitudes (Scotland, Scandinavia). The impact of this will be small, as these countries do not have rainfall shortages.

Temperature

Modest increases in temperature may be beneficial for European agriculture, in particular at higher latitudes where temperature limits the growing season (Scandinavia, Northern Russia). The impacts in Southern Europe will be small, with C4 plants (cereals, maize) most resistant to elevated temperatures.

Extreme events including flooding

The most pronounced impact of climate change on European food production might be related to the impacts of extreme events including floods, droughts and hailstorms. If these would increase, the consequences for agriculture would be significant. The Netherlands would be particularly affected related to its location in the delta of the Rhine and the Meuse, but floods may also substantially hamper agriculture in central Germany and parts of France, as demonstrated by recent floods in the countries.

3.3.3 Uncertainties and research gaps

The uncertainties are substantial. They relate to the precise, local changes in climatic conditions, the ability of farmers to adapt to these changing conditions, as well as the responses of the individual crops and the possibilities to develop and promote more resistant crops, e.g. to extreme events.

3.4 Water management

3.4.1 European level

The impacts on water management are discussed subsequently for the European scale and the Netherlands. This section analyses the potential impacts at the European scale, addressing, (i) flooding; (ii) droughts; and (iii) the hydrological cycle.

Flooding

Flooding is the most common natural disaster in Europe and, in terms of economic damage, probably the most costly one (Estrela et al., 2001). Serious flooding has occurred in the last decade in several European countries ranging from the Mediterranean region (Greece, October 1994, Italy 1994 in the Piedmont area) to the northern counties (Sweden and Norway, 1995). In the English midlands, the flood from the Easter weekend 1998 caused severe damage and the loss of lives. In France, 42 people died in 1992 during the flash flooding in Vaison-la-Romaine, basin wide floods caused widespread disruption and losses in the Rhine and Meuse basins in 1992, 1993 and 1995, and exceptional flooding struck the Po in 1994. In 1997 severe flooding occurred in several parts of Europe: in Greece (January), the Czech Republic, Poland (July) and in Spain and Portugal (November). More recently are the floods (Elbe, Danube and Rhone) in the summer of 2002, which caused severe damage and also caused casualties.

Drought and water availability

The demand for European water resources increases from 100 km^3/year in 1950 to 550 km^3/year in 1990 (Estrela et al., 2001). This demand is expected to increase further. As the pressure on water resources continues to grow, Europe is becoming increasingly vulnerable to the effects of meteorological drought. Recent severe and prolonged droughts have highlighted Europe's vulnerability to natural hazards. Large areas of Europe have been affected by drought over the past 50 years.

In addition, several regions in Europe are dependent on dwindling groundwater supplies. Groundwater supplies are less susceptible than surface water to short-term climate variability; they are more affected by long-term trends. Groundwater serves as the base flow for many streams and rivers. In many areas, groundwater levels are very likely to fall, thus reducing seasonal stream flows. Surface water temperature fluctuates more rapidly with reduced volumes of water, likely affecting vital habitats. Small streams that are heavily influenced by groundwater are more likely to have reduced stream flows and changes in seasonality of flows, likely damaging existing wetland habitats. Pumping groundwater at a faster rate than it can be recharged is a major concern, especially in areas that have no other supplies.

Changes in the hydrological cycle

Continuous warming is the most consistent result among all the GCM integrations of future climate, both globally and over Europe. Model integrations also suggest a continued upward trend in winter precipitation in mid- and high-latitude Europe (IPCC, 2001) and point toward further retreat of European glaciers (Schneeberger et al., 2001). Changes in precipitation extremes, such as an increased proportion of heavy rains and occurrence of very wet seasons are also projected for the future (e.g., Grabs et al. 1996; Frei et al., 1998; Middelkoop et al., 2001; Räisänen & Joelsson, 2001; Jones & Reid, 2001; Palmer & Räisänen, 2002). For Europe these studies suggest that annual rainfall will increase in Northern Europe and decrease elsewhere; temperatures will rise everywhere and potential evapotranspiration will generally increase. The foreseen change in temperature and precipitation will influence the hydrological cycle in a significant way, and changes can be expected in the occurrence of floods and droughts.

The expected sea-level rise will also influence the European coastal water systems, especially the low-lying deltas. Discharge of water to the sea will become more difficult.

3.4.2 National level

For the Netherlands, the impacts on the main drainage basins are discussed, respectively, relating to Rhine and Meuse, Lake IJsselmeer and the North Sea Canal, and the Rhine and Meuse estuary. Subsequently, impacts on regional water systems, water shortages and water surface temperatures are examined.

Rhine and Meuse

Climate change will lead to a change in the discharge regime of the Rhine. The discharge regime will change from a combined rainfall/snowmelt regime to a regime dominated by rainfall. The discharge in winter and spring will increase whereas the discharge in summer and autumn will decrease (Figure 3.3) (Middelkoop et al., 2000). The change in the discharge of the river Meuse will be proportional with the change in projected precipitation. The discharge will increase in the winter season. The effect on the summer discharge for the Meuse is however less clear (De Wit et al., 2001; 2002).

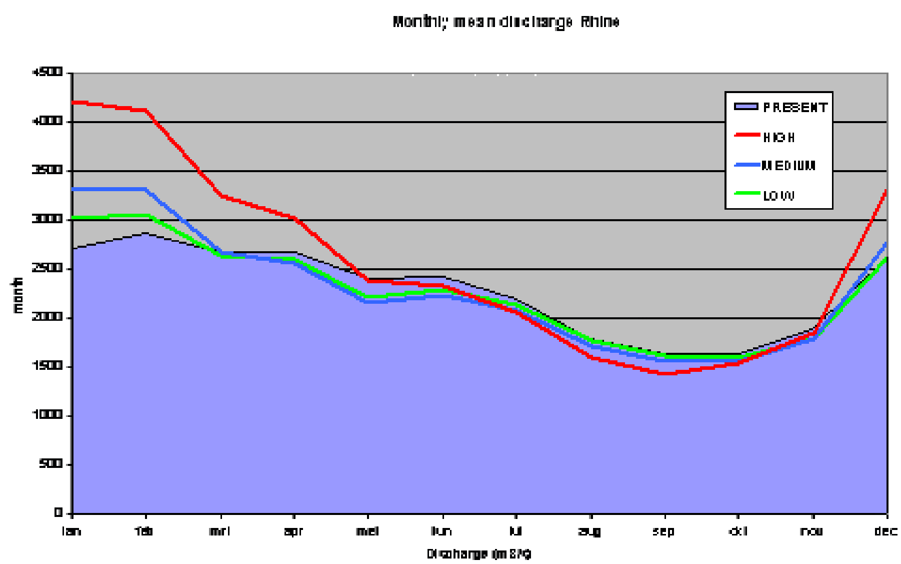


Figure 3.3 Relative change of the monthly mean discharge of the River Rhine (at Lobith) calculated with Rhine flow in combination with UKHI-GCM

Source: Middelkoop et al., 2000.

It is expected that the design discharge of the river Rhine will increase with about 5% per degree temperature increase (Middelkoop et al., 2000). The present design discharge is 16,000 m^3/s. It must however be kept in mind that a discharge of about 18,000 m^3/s is the maximum discharge that can reach Lobith (Silva, 2003). The Meuse, a typical rain river, will react more directly on changes in precipitation. It is therefore expected that the design discharge of the Meuse will increase with 10% per degree temperature increase.

Lake IJsselmeer and North Sea Canal

Due to sea level rise the discharge of water from the lake IJsselmeer into the Wadden Sea and from the North Sea channel into the North Sea is hampered. The amount of water that has to be discharged in winter will increase. This will have the following consequences (Buiteveld & Lorenz, 1999):

The extreme levels of IJsselmeer and Markermeer will rise, namely to the same extent as the sea-level rise. In general there will be greater fluctuations in lake levels, especially in the winter. In very dry summers the lake level may even decrease. The average lake levels will increase with half of the sea-level rise.

In the North Sea Canal and Amsterdam-Rhine Canal higher water levels will occur more frequently and for longer periods, because at IJmuiden it is becoming more difficult to discharge water under free fall. This means that, in the event of a sea-level rise, more will have to be pumped out.

The seepage and with that the salinity in areas surrounding the IJsselmeer will increase by 10%. In the summer the limited water supply will result in water shortage. Due to the changes the following functions are affected:

- Safety;
- Water supply for agriculture;
- Water discharge from the regional water system to the Ijsselmeer;
- And functions that will be influenced by the change in lake levels, such as recreation.

Rhine and Meuse estuary

In the lower part of the Rhine and Meuse there are two aspects which will change due to climate change (Jacobs et al., 2000). Due to lower summer discharge in combination with a sea-level rise it will become more difficult to discharge water into the North Sea. As a consequence there will be more salt water intrusion, which threatens the fresh water supply in that area. The salinity of the water taken may not be too high: a critical level equal to 215 mg/kg is presently the upper limit. During periods of very low river flow and high tide, the salinity of the water in the northern part of the estuary may temporarily exceed the critical level for water intake. At the station along the Hollandsche IJssel, water intake becomes limited when the Rhine discharge at Lobith drops below 1200 m^3/s.

Higher discharge in combination with sea-level rise and possibly more frequent or more intense storm surges will affect the safety.

Regional water systems

The regional hydrological systems in the coastal zone are more sensitive to climate change than the regional water systems in the upper part of the Netherlands because they are exposed to sea-level rise and changed precipitation patterns, as well as soil subsidence. Due to the increase of the extreme precipitation the discharges from the regional water system will also increase in future with 5% till 20%. The number of bottlenecks where water problems or inundation occurs and the frequency of inundations will increase. Salt water intrusion, through estuarine system and through ground water seepage, is expected to increase due to sea-level rise.

Water shortage and low river discharge

Lower discharge of the river Rhine will affect navigation, the fresh water supply for the regional water system, drinking water supply, and as mentioned the salt water intrusion will increase.

Water shortage as occurred in the summer 2003 will become more frequent in the future. The economic damage will increase, up to several billions of Euros in extreme dry summers. Due to climate change the available amount of fresh water will decrease during summer. At the same time it is expected that more fresh water is needed due the economic growth. The fresh water shortage will therefore increase with 10 to 20%, see Table 3.2 (Arcadis et al., 2002).

Table 3.2 Water shortage.

	Shortage Soil			Shortage surface water		
Present	Present	2050 (+1°)	2050(+2°)	Present	2050 (+1°)	2050 (+2°)
Average year	21	25 (+19%)	28 (+36%)	5,7	5,8 (+2%)	6,0 (+4%)
Extreme dry year	143	153 (+8%)	165 (+17%)	12,4	11,7 (-6%)	12,2 (-2%)

Source: Arcadis et al., 2002.

Surface water temperature

Climate change will affect the impact of water cooling by industry and energy production. Water shortage will lead to shortage of cooling water. This problem will be enhanced when the water temperature increases due to climate change. The discharged cooling water may not be higher than 30 °C. With increasing water temperatures the capacity will decrease and will affect the energy production.

3.4.3 Uncertainties and research gaps

Although several potential effects of climate change have been identified, a series of uncertainties remains. Some crucial uncertainties refer to:

- Prognoses of magnitude and spatial variations of future changes in storm-climate;
- The effects of a changing storm climate on geomorphology and ecology; and
- The relation between geomorphological changes and ecological impacts.

3.5 Health

3.5.1 International level

Human health is profoundly affected by natural systems such as the ecology of pests and pathogens, food supplies, water supplies, and weather patterns. The link between weather and diseases is illustrated by the seasonality of many diseases.

Climate change is likely to influence human health in various ways. However, the various parts of the globe will be affected in very different ways due to differences in sensitivity, exposure and adaptive capacity. Climate change may affect health both directly and indirectly, see Figure 3.4.

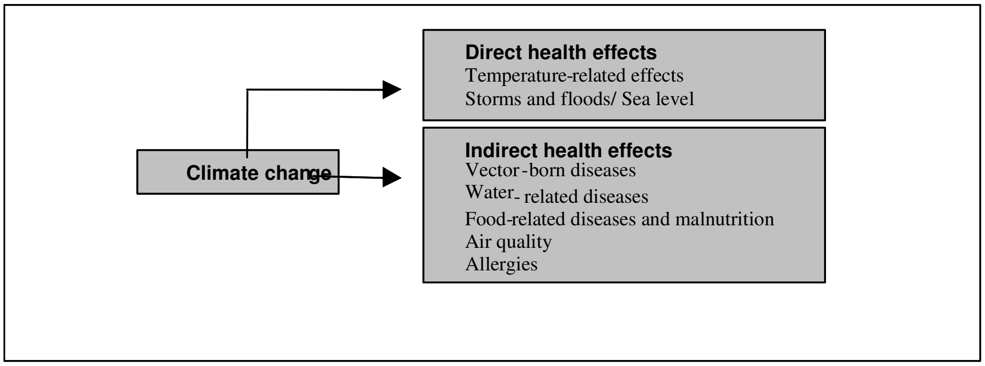


Figure 3.4 Health effects of climate change.

Some geographical areas will experience more harmful changes in their climate (exposure) than others. In addition, some (sub-)populations can be more sensitive to these changes or may be less able to adapt to them in order to reduce the effects. Examples of vulnerable subpopulations include the poor, children, elderly, malnourished people, the chronically ill, people living in coastal areas, urban dwellers and non-immune populations. The extent to which human health is affected depends on: 1) the exposure to climate change and its consequences; 2) the sensitivity of the population to the exposure; and 3) the ability of affected systems and populations to adapt (WHO, 2003). The vulnerability of a (sub-)population depends on factors such as population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care (Woodward, Hales et al., 2000). For instance, in 2001, a group of Dutch stakeholders (e.g. health professionals, policymakers, interest groups, scientists) generally expected that the Netherlands would be capable of coping with possible health effects resulting from climate change. They expected allergy effects and adverse health effects due to poor air quality to be the most important health effects in the Netherlands. In addition, the stakeholders thought that the effects of storm and floods could also be important; although the number of victims may be small, the effects of the incidents are very serious (van Ierland et al., 2001). Health impacts in many other parts of the world are expected to be much more severe than those in the Netherlands. For example, climate change is projected to have a significant influence on the increase in vector-borne diseases in developing regions. The global burden of diseases attributable to climate change has recently been estimated for five geographical areas. Analysing only the better-studied health outcomes (food and water-born disease, malaria, natural disasters, risk of malnutrition), the level of climate change that has occurred since the baseline period (1960-1990) was estimated to have caused 150,000 deaths and 5.5 million DALYs (Disability Adjusted Life Years) in the year 2000, but Table 3.3 shows that there were large geographical differences (WHO, 2003).

Table 3.3 Estimated impacts of climate change in the year 2000.

Region	Total DALYs (1000s)	DALYs/million population
African region	1894	3071.5
Eastern Mediterranean region	768	1586.5
Latin America and Caribbean region	92	188.5
South-East Asian region	2572	1703.5
West Pacific region*	169	111.4
Developed countries **	8	8.9
WORLD	5517	920.3

Source: WHO, 2003; * Without developed countries; ** and Cuba.

3.5.2 European and national level

This section discusses the potential health impacts of climate change at the national and European level. We discuss (i) health effects on floods; (ii) temperature effects; (iii) pollen allergies; (iv) water-related diseases; (v) food related diseases; (vi) air quality; and (vii) vector-borne diseases.

Health effects on floods

Climate change is likely to induce changes in the magnitude and frequency of extreme precipitation events, sea-level rise and associated flooding. In the Netherlands, disease risks from flooding are greatly reduced by a well-maintained sanitation infrastructure and public health measures. Hajat et al. (2003) conclude that in Europe the effect of floods increasing the risk of disease outbreaks appears relatively infrequently, while mental health disorders, like depression and anxiety, are most likely the most important health effects.

Temperature-related effects

The direct influence of temperature on health is demonstrated by the observed increase in mortality during past heat waves (Table 3.4). Much of the excess mortality attributable to heat waves is related to cardiovascular and respiratory disease. Extreme cold also results in an increase in mortality (Huynen, Martens et al., 2001). Global climate change is expected to be accompanied by warmer summers and milder winters. Some studies (Langford and Bentham, 1995; Martens, 1997; Martens & Huynen, 2001) suggest that in many temperate or cold regions a decrease in mortality in winter would possibly counterbalance the increase in mortality during summer. But one also has to account for increased climate variability, which could result in a mortality increase in winter due to cold spells. In addition, the ageing of the Dutch population is expected to increase future vulnerability to thermal stress.

Pollen allergies

Climate and weather conditions influence the timing and duration of the pollen season, the amount of pollen produced and the geographical distribution of flowering plants (Huynen & Menne 2003). In the Netherlands, climate-induced changes in pollen production may affect a large number of people.

Table 3.4 Increased mortality during heat waves.

Heatwave	Impact on mortality
London, July-August 1995 (Rooney et al., 1998)	8.9% increase in mortality over 5-day period
London, 1976 (McMichael & Kovats 1998)	15% increase in total mortality, approximately 520 excess deaths
Belgium, 1994 (Sartor et al. 1995)	13.2% increase in mortality in the elderly
The Netherlands, 1982, 1983, 1990, 1994, 1995, 1997 (Huynen, Martens et al. 2001)	12.8% increase in mortality, approximately 39.8 excess deaths per heatwave day

Water-related diseases

Diseases associated with water are varied and cover multiple environmental pathways. One of the most significant water-borne diseases associated with the public water supply in Western Europe is cryptosporidiosis, which has the potential to infect very large numbers of people. However, there is insufficient evidence to estimate whether climate change would have an impact on this disease. It is unlikely that water-borne diseases will become a serious threat in the Netherlands. There may be some health implications, however, due to an increase in imported cases from less developed regions (e.g. cholera) and from bathing in coastal and surface water of poor quality (e.g. blue algae).

Food-related diseases and malnutrition

Climate change could increase the occurrence of food-borne diseases like Salmonella and Campylobact (e.g. the development of microbes in food is temperature-dependent). However, high standards with regard to hygiene in the Netherlands are likely to prevent any substantial increase in these diseases. Worldwide, food security and malnutrition remain major concerns of climate change, but it is highly unlikely that the Netherlands will be seriously affected.

Air quality

Weather conditions influence air quality via transport and formation of pollutants and can also influences air pollutant emissions (e.g. increased energy demand). Air pollutant problems due to climate change are expected to be more serious in cities.

Vector-borne diseases

Several important infectious diseases are transmitted by vectors such as mosquitoes or ticks. It is anticipated that climate change will affect the vector species, as well as the infective agents (parasites). As a result, global climate change may cause the following changes in vector-born disease transmission: a) the overall incidence and duration of the transmissions season in particular sites may increase or decrease and b) the geographical distribution of disease transmission may change (Kovats et al., 2003). Vector-borne infectious diseases that are believed to be sensitive to climate change are summarised in Table 3.5. With regard to malaria, there may be an increase in risk of occasional local *P. vivax* summer epidemics and it is also possible that the Mediterranean vector *An. labranchiae* may expand into central and Western Europe, presenting a potential for *P. falciparum* malaria infections. However, the chances of the return to a situation of endemic malaria in the Netherlands remain very low due to, for example, an excellent health care system. There could be health implication as a result of the import of malaria cases from less developed regions. A rather new tick-born disease called Lyme disease is now highly prevalent in much of Europe and it is likely that climate change will increase the occurrence of Lyme disease in the Netherlands.

Table 3.5 Vector-borne infectious diseases considered being sensitive to climate change.

Vector	Diseases
Mosquitoes	Malaria, filariasis, dengue fever, yellow fever, West Nile fever
Sandflies	Leishmaniasis
Triatomines	Chaga's disease
Ixodes ticks	Lyme disease, tick-born encephalitis
Tsetse flies	African trypanosomiasis
Blackflies	Onchocerciasis

Source: Kovats et al., 2003.

3.5.3 Uncertainties and research gaps

Although several possible health effects have already been identified, many uncertainties about the link between climate change and health still exist. We identified the following information needs:

- Which indicators of the health effects of climate change can be identified?
- What are the most important uncertainties with regard to the identified health effects and indicators?
- What range of health impacts can be expected when there is a global warming of 2 °C (Article 2, FCCC)?
- How can the acceptable health risk be defined?
- Can this acceptable health risk be translated into climate change thresholds? What level of climate change is dangerous from a health point of view and what adaptations are feasible?
- Which rate/level of climate change should be considered the maximum allowable change from a health perspective?

3.6 Tourism and recreation

3.6.1 International level

Tourism is one of the world's largest economic sectors. It is estimated that tourism directly employs about 8 million people in the European Union, representing roughly 5% of total employment and of GDP (the Dutch shares are similar), and 30% of total external trade in services. Worldwide, the shares attributable to tourism are 2.8% for total employment and 3.8% for GDP (WTTC, 2004).

Tourism is also one of the world's most climate-dependent economic sectors. In some cases, climatic conditions act as a tourist attraction in their own right; in other cases they affect landscapes and influence tourism indirectly. Statistical analyses by Maddison (2001), Lise & Tol (2002), and Hamilton (2003), and a simulation study by Hamilton, Maddison & Tol (2003) show the relevance of climatic factors as determinants of tourist demand. Climate factors are responsible for a large share of the estimated 100 million tourists (Mather et al., in press) that currently visit the Mediterranean region on an annual basis, spending close to 100 billion US dollars. Note that the appreciation for a destination's climate is a relative one, always co-depending on the climate in the tourist's home region. It is the difference in climate that counts. The relative climatic attractiveness of regions varies over the year, co-determining the holiday season.

Landscapes, broadly defined, are also major factors in attracting tourists. Many ski enthusiasts visit the Alps in winter, because they expect to find good snow conditions there. Snow reliability and the length of the winter-sports season both depend on the Alpine climate. Similarly, the presence of a large variety of flora and fauna in a region tend to increase its attractiveness to tourists. Climatic conditions determine the distribution of species to a considerable extent. They also influence the availability of resources that are used by tourism, such as drinking water and energy (e.g. through the availability of cooling water for power plants).

3.6.2 European and national level

Climate change will alter the relative climatic conditions in Europe. Agnew and Viner (2001) explored the impacts of climate change on a range of different destinations. Viner and Amelung (2003) reported on the wider issues that surround the interactions of climate change with tourism and the environment. Climate change can have both direct and indirect effects on tourism. The direct roles of climate and climate change can be thermal (factors related to thermal perception by tourists, e.g. temperature, humidity), physical (e.g. wind, air quality) or aesthetic (e.g. sunshine) in nature (De Freitas, 2001). The indirect impacts are on landscapes and resources availability. Below, we examine (i) the impacts on demand; (ii) the impacts on supply; (iii) impacts on landscapes; and (iv) impacts on resources.

Direct impacts on demand

A limited number of tailor-made climate indices (maximum score: 100) have been composed for tourism that incorporate the thermal, physical and aesthetic roles of climate; a few of them have been applied to climate change to assess its effects on climatic attractiveness for tourism. Using an index developed by Hatch (1988), Rotmans et al. (1994), it was found that the Mediterranean will lose much of its attractiveness in summer, while summer conditions will improve in the countries in the north of Europe. With the tourism climatic index developed by Mieczkowski (1985), Amelung and Viner (forthcoming) similar conclusions are reached (Figure 3.5). Whereas in a typical southern European destination such as Antalya (Turkey) conditions are projected to improve in spring and autumn and worsen in summer, conditions for De Bilt (Netherlands) are projected to improve in spring, summer and autumn: the high season will start earlier and end later.

In addition, Amelung and Viner conclude that summer will cease to be the most pleasant season for tourism, which it is now in all of Europe (see Figure 3.6a). In the second half of the century, a large share of the Mediterranean is projected to be characterised by a bimodal distribution, with the most pleasant conditions occurring in spring and autumn.

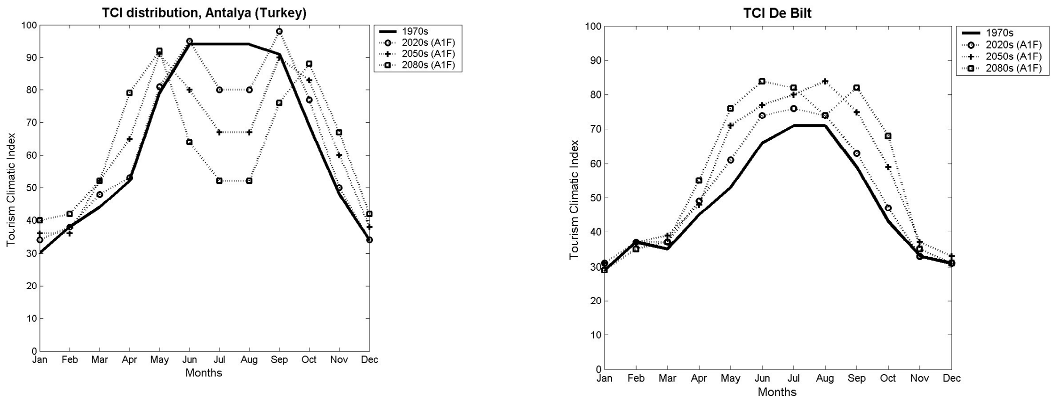
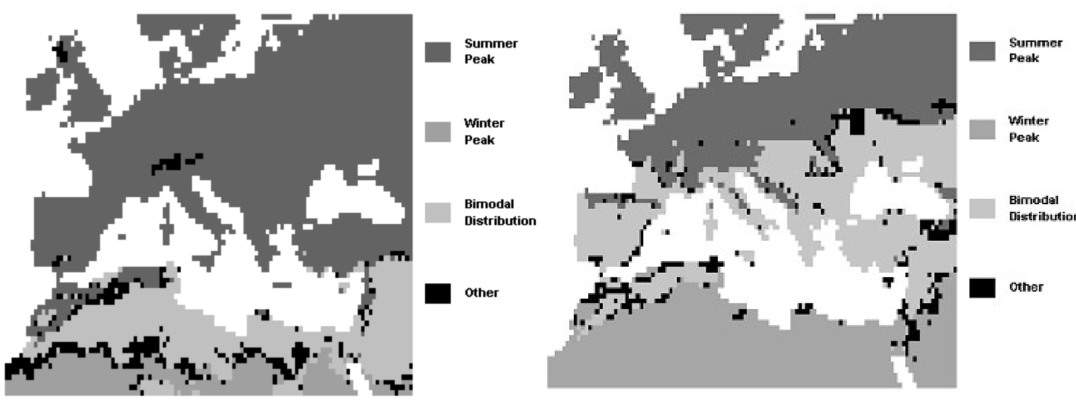


Figure 3.5 Historical and projected scores on Mieczkowski's tourism climatic index (TCI.).

Note: Data is for throughout the year for the typical southern city of Antalya and the Dutch weather station of De Bilt.

These changes will likely induce a significant share of Dutch and other northern European tourists to spend their summer holidays in their own region instead of the Mediterranean region. Such shifts may be reinforced by climate policies that affect transport. Currently, the air travel industry is in a favoured position: taxes on kerosene and VAT rates on tickets are low, and emissions from international transport are not included in the Kyoto Protocol. Changes in this situation are almost inevitable, and these will most likely lead to significant increases in travel costs.



(a) (b)

Figure 3.6 Climatic seasonality in tourism in the historical situation of (a) 1961-1990, and in the future situation of (b) 2070-2099 (SRES A1F scenario).

(See Figure 3.5b for the results of the SRES A1F scenario of rapid climate change).

Not all types of tourism are equally climate dependent. The climatic conditions required for Sun-Sea-Sand tourism, for example, are much stricter than those required for cultural tourism. In the first case, the climate is a primary motive for visiting a particular area, while in the second case it is not, although weather conditions may influence tourists' ultimate activity patterns in the destination area. It can therefore be safely assumed that climate change will have a greater impact on climate dependent tourism (such as beach tourism) than on weather sensitive tourism (such as cultural tourism). In urban areas, however, the level of smog is known to increase with temperature. As a result, climate change may well lead to deteriorating health conditions in Europe's cities in the summer season.

Direct impacts on supply

The amount of precipitation and the frequency of extreme weather events are expected to increase in the Netherlands in the coming decades. Extreme events can damage tourism-related real estate and infrastructure. The number of great natural catastrophes has almost tripled since the 1960s, increasing the overall cost to the world's economies eightfold, and the cost to the insurance industry fifteen fold between the 1960s and the 1990s (Schinzler, 2001). This trend is projected to continue as a result of climate change. In particular areas that are prone to hurricanes or floods, such as small island states in the Caribbean or Pacific, are at risk. Damage to the Dutch tourist industry will likely be relatively small compared to other climate change effects. Insurance premiums may however increase significantly.

Indirect impacts on landscape

Climate change will affect the natural and cultural attractions in destinations. For example, landscapes are expected to change as a result of shifting ecosystems, and increased levels of carbon dioxide in the atmosphere will potentially increase weathering or accelerate deterioration of materials (Smith et al., 1998), affecting cultural heritage.

Snow is an essential element of a landscape to be suitable for winter sports, which are very popular among the Dutch. Today, 85% of Switzerland's 230 ski resorts can be considered snow-reliable; they are located 1200 meters above sea level. If the snow reliability line were to rise to 1500m as a result of climate change (year 2030 - 2050), the number of snow-reliable ski resorts would drop to 63%. According to rough estimates, a temperature change of one degree in the Alps can shift the snow line up by 100 to 200 metres (Schär et al., 1998). If the line of snow reliability rises to 1,800 metres, under a more acute warming scenario, only 44 percent of skiing regions would be snow-reliable (Bürki et al., 2003).

Coastal zones are particularly vulnerable to climate change as a result of sea-level rise and an increased frequency of extreme events. At the same time, these coastal zones are where most tourism is concentrated. On the Dutch coast, sea-level rise will increase the transport of sand from the western coast towards the Wadden Sea; simultaneously, the projected increase in gale frequency will accelerate the erosion of beaches and dunes. For the Netherlands, which has a substantial tidal difference, the consequences of a gradual sea-level rise are expected to be limited. The situation is different for the Mediterranean, in which tides do not play a major role. Coastal facilities are typically adapted to a narrow range of water levels. Any significant sea-level rise will jeopardise the coastal infrastructure, including marinas, in the Mediterranean. For small island states in the Caribbean and the Pacific, popular among tourists, threats from sea-level rise are existential; these states may completely vanish.

Climate change is likely to have an impact on nature and landscapes, two major factors of attraction in tourism. Ecosystems will be forced to migrate towards the poles; some species and ecosystems will be better able to follow this speed than others, so that species compositions change. As a result, nature and landscapes will start to look different. The relevance of these changes will differ between tourists depending on their 'love for nature', which can vary from superficial to deep and lasting (Lengkeek, 2000). Most tourists' love for nature is somewhere in between these two extremes, with aesthetics being more important than in-depth knowledge of natural systems. It is therefore likely that landscape changes will only affect tourism if the landscape's aesthetic qualities are significantly altered. The effect of climate change on nature also has a health component: the temporal and spatial distributions of allergies and diseases will change. In the Netherlands, for example, the pollen season will be extended, affecting millions of tourists suffering from hay fever.

Indirect impacts on resources

Water use should be seen as an important issue, because many regions face water scarcity. Tourism often seems to accelerate existing problems because tourists shift their water demand to other regions, often water scarce areas like coastal zones. Water consumption by tourism is relatively high. WWF (2001) reports that the average tourist in Spain consumes 440 l per day, a value that increases to 880 l if swimming pools and golf courses are taken into account. This compares to an average use of, for example, 135 l per day in Germany (Gössling, 2002). In many tourist destinations, especially in southern Europe, peak demand for water from tourism coincides with peak demand from other sectors, such as agriculture. In addition, precipitation is often lowest in the holiday season. Climate change is predicted to exacerbate this situation. Competition for water between tourism and other sectors will become fiercer in many regions of Europe, in particular in the holiday season. On the popular island of Majorca, for example, soil moisture and groundwater levels will almost certainly decline in the 21st century. Most of Majorca's water is currently supplied from groundwater sources (Kent et al., 2002). These sources are under further threat as a result of sea-level rise, leading to contamination of freshwater sources.

The hot summer of 2003 has shown that water shortages and high water temperatures can also have major effects on power plants that rely on water for cooling purposes; in France and the Netherlands the situation was critical. During heat waves the need for cooling is not only urgent in the power stations, but in society at large, which results in an increased demand for energy to power the air-conditioning.

3.6.3 Uncertainties and research gaps

Although tourism is a climate dependent industry, little is know about the influence of climatic conditions on visitation levels, profitability, and tourist attractions and facilities. The impacts of climate change are therefore highly uncertain. Major uncertainties relate to:

- The climate sensitivity of destination choice processes;
- The climate sensitivity of recreation patterns;
- The level of beach erosion;

- The long-term impact of heat waves on the selection of holiday destinations;
- Climate thresholds of profitability in the tourist industry;
- The level of water scarcity in dry holiday areas;
- The impact of climate policies on transport prices and volumes.

3.7 Coastal zone management

3.7.1 International level

Although the coastal zones in different parts (climate zones) of the world face different impacts of climate change in terms of rise in sea level, in frequency and magnitude of storms, cyclones and typhoons and in sea water- and air temperature, the following global key concerns can be formulated:

- The world's largest cities (>10 million people) are located in the coastal zone. These cities face major population growth which, combined with the impacts of climate change, result in a huge increase of the risk (from 200 million people at risk in the coastal zone in 1990 to 400 million in 2050);
- Large-scale climate related processes (like the Gulf Stream, El Nino) influence both large-scale and local ecosystems (like migrating fish, coral reefs in international waters). An international policy approach is necessary;
- Mangrove forests are specifically vulnerable to small changes of water level and temperature. This will have a major negative impact on;
  - The ecosystems of mangrove forests and related ecosystems;
  - The natural coastal protection by mangroves.
- The institutional framework is not capable of developing and executing adequate policies to threats of sea-level rise and population growth in the coastal zone due to lack of resources. This holds especially for developing countries;
- In a socio-economic sense, developing countries will become relatively more vulnerable to the effects of climate change. Especially, ecosystems will suffer from this. Examples are:
  - Coastal wetlands disappearing due to coastal erosion and coastal cultivation (aquaculture);
  - Estuarine ecosystem disappearing due to the use of all fresh (river) water by human beings. This is partly the result of adapted water management because of hydrological change related to climate change;
  - Sediment supply to the coast by rivers is disappearing due to damming of river, resulting in unwanted coastal erosion;
  - Lack of natural fresh (ground-)water resources in the coastal zone due to extensive human use and changing hydrological regime (rainfall).

For a reference to the situation in the Netherlands, two examples from studies between 1995-2000 under the Netherlands Climate Change Studies Assistance Program (NCCSAP) show the impacts of climate change on the coastal zone for (semi)tropical climates in the table below.

Table 3.6 Impacts of climate change on the coastal zone.

Country	Climate scenario	Economic scenario	Impacts (without adaptation measures with 100 cm SLR in 2100)
Bangladesh	SLR: 100cm/100yr Prec: monsoon +33% winter +22% Evapor. monsoon +15 % winter +20% River discharges (no upstream developments taken into account) Peak flows +13% Low flows -22% Cyclone intensity +25%	-BAS 3.4% ann. Growth GDP up to 2010 - High Devel: 5,7%.	- 90% of population at risk of annual flooding in 2010 with 10cm SLR - Up to 10% of GNP at risk annually in 2010 with 10 cm SLR - Up to 100,000 km^2 area at risk for annual flooding with 10 cm SLR in 2010
Vietnam	SLR: 100cm/100yr	- 5-10% ann.growth up to 2025 - Difference mountains-coast	-Ca 17 million people at risk due to annual flooding - Ca US $ 17 billion (80% of GNP) at risk due to annual flooding - Ca 1,750 km^2 at risk (60% of Vietnam´s coastal wetlands)

3.7.2 European and national level

The key potential impacts on the coastal zone at the European level are:

- Spatial differences in sea-level rise over Europe due to differences in vertical land movement and in local sea-level rise;
- Effects of storm frequency and magnitude, and of temperature rise are not yet fully understood, but may vary considerably per location;
- Millions of people are at risk in the coastal zone (in the year 1990: 26 million people), most of them living in the cities located in low lying areas at the North Sea, North Atlantic and the Mediterranean coasts that are of significant socio-economic importance;
- A growing number of people in the future at risk by flooding from sea due to: population growth in coastal areas, rate of sea-level rise and lack of protection measures taken (the increase ranges from 300 to 130000 % by the year 2080 depending on the sea-level rise and the protection measures taken);
- Ecological values of salt marshes and wetlands are under pressure (the current area of 10000 km2 faces a loss of 6 to 25 % by 2080), due to coastal squeeze where the area of salt marches diminishes due to coastal erosion at the sea side and hard protection measures at the land side; inundation of intertidal area due to sea-level rise; and socio-economic activities indirectly polluting and disturbing and directly taking over salt marsh areas;
- There is a need for integrated (multi-disciplinary) and cross-border (international) strategic management approaches, addressing the human utilisation of the coastal zone and preservation of ecosystems given the sea-level rise.

In the Netherlands, the Wadden Sea and adjacent North Sea coast are particularly vulnerable: The main climate change impacts on coastal zones are examined below, respectively with reference to (i) morphology; (ii) ecology; (iii) changes in storms; (iv) combined impacts; and (v) impacts on human use.

Morphology (50-150 years)

Sea-level rise, a changed river discharge and the changes in the storm-climate and wave-action will result in a changed morphology along the Dutch coast. The following impacts are expected:

- The rate of sea-level rise is strongly determining tidal marsh and -flat development. Above a critical level they will not be able to keep up with sea-level rise by sedimentation, and by consequence flats and marshes may 'drown'. For tidal marshes this critical level of sea-level rise is 8.5 mm/year; for tidal flats in larger tidal basins 3 mm/year, and in small tidal basins 6 mm/year;
- Stronger wave attacks and more extreme torrential rain events may induce increasing cliff erosion of tidal marshes leading to a decrease in areal;
- The effect on tidal flats of changes in storminess and wave climate are still very uncertain;
- The increasing sediment demand in the tidal basins, will trigger a faster erosion of the sandy North Sea coasts. Combined with the direct effect of a rising water level, estimates of the total coastal erosion in the Netherlands show an increase of 250% at 6 mm/year and of 330% at 8.5 mm/year, relative to the erosion at the present rise level of 2 mm/year;
- Higher water levels will also influence the unprotected parts of barrier islands, probably resulting in a start of acceleration of erosion.

Ecology (50-150 years)

The changes in the ecology of the coastal zone, due to climate changes, are expected to be relatively minor until 2050. However, from 2050 estimates of ecological changes due to increasing air- and water temperatures are:

- Faster growth of bacteria;
- Change in species of phytoplankton (also due to changes in the nutrient-supply);
- A growing concern on the import of new and possibly harmful algae via ballast water in ships, accelerating the invasion of new species;
- An increase of sea grasses;
- A shift in species on land and in the sea. For example a strong impact on different fish populations is expected since fish cannot adapt well to changing temperatures.

Changes in storm-climate and in hydro- and morphodynamic conditions

Changes in hydro- and morphodynamic conditions are expected to have the following ecological impacts:

- A decrease of relatively immobile epibenthos like oysters and mussels;
- Changes in extreme discharge of fresh water will probably only have local effects, although salinity stratification may influence estuaries;
- Local shifts in species could be expected due to shifting brackish gradients;

- On the barrier islands changes in plant species in the lower dune valleys and a possible enhancement of peat growth might be expected as a result of higher ground water tables due to sea-level rise;
- In general, the biomass of benthos in the Wadden Sea will probably decrease due to a decrease in shoal height;
- Loss of tidal-marsh habitat due to an expected increase in cliff erosion;
- Shifts in fish species using the Wadden Sea as a nursery, due to morphological changes.

Combined impacts

Different factors combined can have the following ecological impacts:
- Viral infection may increase due to habitat loss for different species and increased river discharges;
- Bird abundances and species assemblages may change due to the change in food availability and a change in the areal extent of roosting and foraging grounds, due to erosion of (lower) tidal flats and to temperature changes;
- In general it is thought that mammals may be influenced by the change in availability of food species; however, the exact effect is not known;
- A decrease of high shoals and viral infections might influence the success of the common seal in the Wadden Sea;
- Changing temperature and salinity, wind directions and seawater temperatures, river discharges and changes in the North Atlantic Oscillation-index, may induce much more, still unknown ecological changes. For example it is not known if the growth-rate of zooplankton species will increase or decrease due to climate change.

Impacts on human use (50-150 years)

The general impacts on the human use of the coastal zone are analysed below. In addition, the expected ecological “impacts” for the period 1990-2090 are summarised in Table 3.7.
- The protection function of the coastal zone against flooding of the hinterland will be weakened and the risk of damage will increase, leading to the need of counteractions and extra investments for nourishments and coastal protection works;
- Harbour infrastructure will need some extra investments to adapt to higher water levels;
- Gradual changes in tourism may change (not expected in the first 50 years, except if water quality changes due to, for instance, new toxic algae) due to changes in eco-system;
- Changing possibilities of the fishing industry due to the changes in the eco-system.

3.7.3 Uncertainties and research gaps

Although several potential effects of climate change on the coastal zone have been identified, a series of uncertainties remains. Some crucial uncertainties refer to:

Table 3.7 Expected ecological "impacts" for the period 1990-2090.

Reduction marshes	20 km^2
Reduction intertidal areas	224 km^2
Benthic primary production	6.4 % increase for total area
Sedimentation of organic matter	20 % decrease per unit area
Biomass filter/deposit feeders	36.8 % increase for total area

Source: ISOS 1991 document.

Sea level rise:

- A lot of research has been done on the global sea level rise with a high range in model outcomes. Still, there is a high uncertainty on the absolute level to be reached in future;
- As a result, the local effects (ie. sea level rise for the North Sea and the associated wave climate) are unclear;

Storm climate:

- Prognoses of magnitude (extreme values) of future storms;
- The variations in time and space of the changing storm-climate;
- The effects of a changing storm climate on geomorphology and ecology.

Ecology

- The relation between ecological impacts and geomorphological changes.

Scenarios and methods for adaptation:

- It is yet unclear how society can and will react on the long term effects of climate change.

3.8 Summing up vulnerability, risks and indicators

On the basis of the analysis in this chapter, we conclude that the following indicators are of relevance to the situation in the Netherlands. In the area of ecosystems, indicators include shifts in species ranges, shifting of vegetation belts, change in growing season, changes in biochemical cycles, increased flooding of (coastal) ecosystems, hydrological changes in estuaries, changes in distribution patterns of species, extinction of species not able to adapt, and changes in ecosystems.

In the area of food supply, the most important indicators are at the global level and include the impacts on crop production, and fish migration and production. Apart from the direct impact, food supply is especially important for developing countries, where large parts of the population are working in (small scale) agriculture and fishery, thus forming the major "employer" in remote areas. At the national level, food supply is not necessarily affected.

The largest impacts on the Netherlands will occur via the impact on water management. Important indicators for the impact of climate change on water management include flood risk, water shortage, energy supply (allowable cooling water discharge), navigability of rivers, salt water intrusion, impacts on drinking water, irrigation water, industrial water, and the increasing length of drought periods.

The impacts on health can be categorised as direct (via rise in temperature) and indirect (e.g. via infectious diseases, allergy) impacts. Analysing only the better-studied health outcomes, the level of climate change that has occurred since the baseline period (1960-1990) is estimated to have caused 150.000 deaths and 5.5 milion DALY's in the year 2000, with large geograhical differences. Health impacts in many other parts of the world are expected to be much more severe than those of in the Netherlands. In 2001, a group of Dutch stakeholders generally expected that the Netherlands would be capable of coping with possible health effects resulting form climate change. They expected allergy effects to be the most important health effects in the Netherlands. Other useful indicators for climate related health effects in the Netherlands include mortality during heat waves and the spread of certain infectious diseases like Lyme disease.

Tourism can be subdivided into climate and weather depending tourism. Only the first kind of tourism, in which the destination chosen is based more on the local climate than on the cultural values, is important in the climate debate.

Tourists and tourist services are flexible in their capacity to adapt to climate changes. However, the tourism *infrastructure* is more vulnerable. The more investments done in the past, the more vulnerable the area will be.

Changes in the global climate may have a strong impact on the coastal zone by the changes in hydrology (river discharges into open sea), hydraulic phenomena (wave/storm-climate, sea level and sea-level rise), morphology (sedimentation patterns, coastal retreat), ecology (terrestrial and marine) as well as many aspects of human use (safety, socio-economic developments). These aspects have their own characteristic adaptation capacity (with different spatial and time scales). For the coastal zone, the most important indicator is the rate of relative sea-level rise (rise in mm/year) determining the capacity of a system to adapt to the new conditions.

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4. Adaptation options and possible climate change impacts and threshold values

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4.1 Introduction

In the previous chapter, the impacts of climate change have been discussed. Analysis of the scales, magnitudes and potential socio-economic and ecological consequences of these impacts allows the assessment of the need to enact policy aimed at adaptation to these impacts.

This chapter analyses the adaptation options to climate change for the relevant sectors. During the stakeholder consultation process, stakeholders discussed potential types of adaptation options, and priorities in the implementation of adaptation measures. Based upon the stakeholder participation process, the main adaptation options have been further examined. The assessments are based upon a review of recent scientific literature.

We will subsequently discuss the adaptation options for climate change on ecosystems (Section 4.2), food production (Section 4.3), water management (Section 4.4), health (Section 4.5), tourism (Section 4.6) and coastal zone management (Section 4.7). We will discuss adaptation options themselves, and we subsequently indicate, for each category the indicators and thresholds that have been identified by the stakeholders as critical for adaptation, i.e. stakeholders indicated that adaptation in order to avoid the related thresholds was their key priority in dealing with climate change.

4.2 Ecosystems and ecosystem services

4.2.1 Adaptation options

It is important to remember that ecosystems are dynamic systems that have a certain resilience to adapt to changing environmental conditions. The main issue at stake is therefore not that environmental factors change, but that they are changing so rapidly (temperature, rainfall, extremes, etc.).[19] In addition, ecosystems are increasingly exposed to other threats, such as eutrophication and physical disturbance (roads, buildings, etc.) in the Netherlands and other densely populated areas, as well as overexploitation of many natural resources (forests, fish stocks) worldwide. These other threats act in conjunction with, and may exacerbate the problems caused by climate change.

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[19] Hence, Article 2 UNFCCC aims to stabilize greenhouse gas concentrations at a level to prevent dangerous anthropogenic interference with the climate system "*within a time-frame sufficient to allow ecosystems to adapt naturally to climate change*".

Obviously, it is highly important to monitor changes in ecosystems and species distribution and behaviour in order to be able to respond adequately to climate change induced pressures on ecosystems.

Generally speaking, adaptation measures for ecosystem may be divided into two categories (van Ierland et al., 2001):

- Measures aimed at creating conditions under which species have sufficient possibilities to adapt; and
- Measures aimed at reducing other threats to ecosystems (such as disturbance, acidification, overexploitation).

Measures aimed at creating conditions under which species have sufficient possibilities to adapt

In two ways, favourable conditions can be created for the adaptation of ecosystems. First, ecosystems can be connected and given the space to adjust. This is important to ensure that species with restricted mitigation capacities are able to resettle themselves following climate change. An example of this is the Ecological Main Structure (EMS) proposed for the Netherlands. Ideally, an EMS should also be realised in a European context. If completed, this will enhance the migration possibilities of species through the countries. Note that this may require re-evaluation of our definition of exotic species; if Southern species move into the Netherlands, they may need to be considered part of the indigenous ecosystems under the altered climatic conditions. Second, ecosystem resiliencies should be maintained in order to ensure that ecosystem keep the intrinsic capacity to adjust to climate change. Resilience depends upon a range of factors, such as the biodiversity and the nutrient status of the system (e.g. Scheffer et al., 2001).

Measures aimed at reducing other threats to ecosystems

As climate change induced disturbance act jointly with other threats to ecosystems (such as disturbance, acidification, overexploitation), it is possible to partly mitigate the impacts of climate change through reduction of other disturbances, such as recreation, land use conversion, disturbance, etc. (which also helps to maintain ecosystem resilience).

4.2.2 Indicators and thresholds

Indicators to monitor the ecological impacts of climate change, and the effectiveness need to be specified at both the species and the ecosystem level. A possible outlook for a set of global indicators at the species level is presented below. In Table 4.2, the key national indicators and thresholds, as identified by the stakeholders, are presented. A complicating factor for stakeholders appeared to be the identification of acceptable and unacceptable levels of loss of species and biodiversity. Legal norms for species loss are not well defined; although there are several national, supranational and international laws and agreements that define the requirements on species protection, there is no specification of which loss of species would be acceptable.

Table 4.1 Threatened and extinct species per species group.

	No. of species in group	Approx. proportion of group assessed	Threatened species in 2000	% of total in group threatened	Extinct species
Vertebrates					
Mammals	4,763	100%	1,130	24%	87
Birds	9,946	100%	1,183	12%	131
Reptiles	7,970	<15%	296	4%	22
Amphibians	4,950	<15%	146	3%	5
Fishes	25,000	<10%	752	3%	92
Invertebrates					
Insects	950,000	<0.1%	555	0.06%	73
Molluscs	70,000	<5%	938	1%	303
Crustaceans	40,000	<5%	408	1%	9
Others	>100,000	<0.1%	27	0.02%	4
Plants					
Mosses	15,000	<1%	80	0.5%	3
Confiers, cycads, etc.	876	72%	141	16%	1
Flowering plants	138,000	<9%	5,390	3.5%	86

Source: CBD, 2002.

Table 4.2 Selected key national indicators and thresholds.

Indicator	Acceptable risk	Unacceptable risk
Loss of species		Where the legal norms are exceeded
Changes in biodiversity		

Source: Stakeholder interviews.

4.3 Food supply

4.3.1 Adaptation options

Agricultural systems can adapt to climate change through changes in crop choice, water management, reclamation of land, research programs and organisation structure (van Ierland et al., 2001). Some farm level adaptation strategies, such as changes in planting and harvest dates, crop rotation and crop varieties, can be incorporated without large changes in management practises. Longer term planning is required to stimulate research on drought tolerant crops, enhanced irrigation techniques and other adaptation techniques. The adaptation to extreme events is particularly cumbersome, this requires timely action and long-term capital investments, for example in water storage reservoirs.

Climate change may particularly affect rangelands, where livestock keeping is the most important agricultural activity. The impacts of climate change need to be assessed in consideration of the current degradation of such systems through overgrazing, as in for example the Sahel. Hence, adaptation options also need to consider the two impacts, in particular because it has recently been shown that high grazing pressure reduces the resilience of such systems for climate variability and droughts (Hein & Weikard, 2004). Adaptation options involve reduction of grazing pressures, as well as enhancing the livestock markets in these countries so that the farmers can more adequately respond to drought by selling livestock.

In the Netherlands, the impacts on other agricultural sectors, such as dairy farming or greenhouses are expected to be small (van Ierland et al., 2001). Higher groundwater levels in the west due to wet summers may reduce the grazing potential. The greenhouse gas sector may benefit from higher atmospheric CO_2 levels, and higher temperatures (which reduce the energy demand), but it may be adversely affected by extreme events (hail storms, droughts). Adaptation options will have to be sought in terms of specific measures, such as enlarging water storage reservoirs.

4.3.2 Indicators and thresholds

A table presenting a preliminary set of indicators to monitor the impacts of climate change, and the effectiveness of adaptation measures, on agricultural production is listed in Table 4.3. Stakeholders points-of view on crucial indicators and thresholds at the level of the Netherlands is indicated in Table 4.4.

Table 4.3 Potential indicators to monitor agricultural adaptation measures.

Indicator	Units
Crop yields, per hectare, per crop	Ton/ha
Areas per crop	Ha
Irrigation needs per crop	l/ha
Percentage of drought resistant crop varieties used	%
Planting dates	Date
Harvest dates	Date
Costs of adaptation measures, such as reservoirs	Euro/year

Table 4.4 Selected key national indicators and thresholds.

Indicator	Acceptable risk	Unacceptable risk
Productivity to land		When the losses are structural
Access to food		

Source: Stakeholder interviews.

4.4 Water management

4.4.1 Adaptation options

The Commission Water Management 21st century (CWB21, 2000) was formed in response to a number of floods by the end of the end of the 20th century. The question it needed to answer was: “how to prepare our water management for the 21st century”. The main strategy of retention/storage/discharge is expected to improve flood safety and reduce water shortage while creating opportunities for nature and recreation. The commission also calculated the costs which are needed in water management in dealing with floods and droughts (around €1.2 billion). The commission calculated the additional yearly costs up to the year 2050 which are needed to adapt to the effects of climate change, based on the +2 °C climate scenario for the year 2100. For the head water system (Rhine and Meuse, IJsselmeer Area and the coast), these amount to € 180 million. For the regional water systems, the adaptation costs are some € 45 million

Based on the work of CWB21 it can be concluded that it should be possible to mitigate the effect of a moderate climate change for the water sector. Several studies were initiated after WB21, such as the "Droogtestudie Nederland" and the study on the additional discharge capacity of the sluices of the IJsselmeer. Also in the key planning decision (PKB) "Room for the River" higher design discharge due to climate change is an issue. The possible measures are estimated as follows:

- Rhine and Meuse: Due the expected higher design discharge of river Rhine and Meuse studies have been done to investigate the mitigation options. At the moment the process of the PKB Room for the River is running. The aim of the PKB is to describe the measures that are needed with which it is possible to comply with the design discharge by the year 2015. However the PKB Room for the River not only looks at these short-term goals. It also has to investigate if the measures which have to be taken for the short-term goals fit with (additional) measures which are necessary to cope with a further increase of the design discharge of the Rhine up to 18.000 m^3/s and the Meuse of 4600 m^3/s for the end of this century;
- Lake IJsselmeer and North Sea Canal: In order to maintain the lake level dynamics at the present level, up to the year 2050, plans are made to expand the discharge capacity. The start of the building of the extra discharge sluices is foreseen for the year 2008 and has to be ready by the year 2013. The foreseen budget will be about € 242 million. Increase of the capacity of the pumping station at IJmuiden will be realised by the mid of 2004. This measure must guarantee that the dynamics of the water levels in the North Sea Channel will stay at the present levels and can be maintained at these levels in future (next 50 years);
- Regional water system: The regional water system has to be adapted to discharge the larger quantities. Because of the increasing sea level this can only be done by increasing pumping capacity;
- Water shortage and low river discharge: Lower discharge of the river Rhine will affect navigation, the fresh water supply for the regional water system, drinking water supply, and as mentioned the salt water intrusion will increase. The damage for agriculture will increase the next 50 years up to 25 to 35 % per hectare. The total economic damage will vary from half million Euro in an average year up to several million Euro in an extreme dry year. Also nature will suffer from fresh water shortage. In extreme dry years irreversible damage can occur. The distribution of surface water within the Netherlands will be adapted in order to prevent irreversible damage. The so-called "Verdrogingsreeks", which regulates the priority of the water distribution in drought situations, will be changed;
- Surface water temperature: Climate change will affect the impact of water-cooling by industry and energy production. Water shortage will lead to shortage of cooling water. This problem will be enhanced when the water temperature increases due to climate change. The discharged cooling water may not be higher than 30 °C. With

increasing water temperatures the capacity will decrease and will affect the energy production. Mitigation is possible by transferring power plants to places with better cooling possibilities.

Figure 4.1 Picture from RWS Netwerk June 2004. One of the two additional pumps for the discharge station IJmuiden. This is at the moment the discharge station with the largest discharge capacity in Europe.

4.4.2 Indicators and thresholds

The climate impact studies on water management in general use the +2 °C scenario (2100). For the determination of the increase in capacity of the discharge sluices of the IJsselmeer this scenario is used. The studies studied indicate that the effects of climate change can be dramatic, however when the mitigation or anticipation starts in time it should be possible to adapt. Problems occur when changes go faster than expected or when no anticipation takes place. In that case risks can be unacceptable. Because water management in general uses the +2 °C scenario, stronger increase can be indicated as an unacceptable risk.

Critical thresholds include:

- Design discharge Rhine and Meuse: In the PKB Room for the River takes in to account a future increase of the designs discharge based on the +2 °C scenario for 2100. Increase of the design discharge of Rhine above 18.000 m^3/s and for the Meuse above 4600 m^3/s could be indicated as unacceptable;
- Navigation: The indicator for navigation on the Rhine Branches is the OLR (Overeengekomen Laagste Rivierstand). The water level may be lower than the OLR in 5% of the time;

- Surface water temperature: Water temperature is critical for the aquatic ecosystem. At the moment the threshold level is 30 °C. Temperature of surface water is important for cooling water for energy production and for industrial cooling water;
- Blue green algae: In stagnant water and lakes the presence of blue-green algae can be used as an indicator. There is a positive relation of the temperature with the presence of (unwanted) blue-green algae.

4.5 Health

4.5.1 Adaptation options

Populations with a low adaptive capacity are more vulnerable to the health effects of climate change than populations with a higher ability to adapt; what may be manageable for one region may be overwhelming for another. Table 4.5 shows that possible adaptation strategies to mitigate the health effects of climate change cover a wide spectrum. A simple example is that of reducing the extra deaths and episodes of serious illness experienced by urban populations during extremes of heat. Adaptation options could include 'weather-watch' warning systems, better housing design, climate-related urban planning (to reduce the 'heat island effect'), and greater access to emergency medical care.

A population's adaptive capacity concerns the ability to adjust to climate change in order to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. It is determined by factors like economic resources, technology, information and skills, infrastructure, institutions and equity (WHO, 2003). The success of adaptation strategies will also rely on the involvement of local and national communities in the decision-making process, which in turn is dependent on an effective programme of information sharing and dissemination. As far as possible, adaptive interventions should be undertaken on the basis of evidence that demonstrates their effectiveness. Little is known about the biological or passive adaptation of humans to climate change. Most assessments of the health impacts of climate change have not addressed adaptation explicitly.

The health status of a population is an important integrating outcome that reflects a range of other environmental impacts. Therefore, awareness of the potential health impacts of climate change should have substantive implications for policy-making in the various "upstream" sectors (environment, industry, public water supplies, construction, agriculture, etc.) that would mediate some of the effects of climate change. Many adaptation options may have benefits beyond those associated with climate change, as they include measures such as the strengthening of the public health infrastructure, health education, and monitoring and surveillance.

In 2001, a group of national stakeholders (e.g. health professionals, policymakers, interest groups, scientists) argued that the Netherlands will be capable of coping with possible health effects resulting from climate change. Possible measures that they frequently mentioned to reduce the impacts included education and monitoring.

Table 4.5 Adaptation options for reducing the health impacts of climate change.

Health outcome	Legislative	Technical	Educational-advisory	Cultural and behavioural
Temperature-related effects	Building guidelines, greater access to (emergency) medical care	Housing, public buildings, air-conditioning, isolation, heating, urban planning	Early warning systems, maintain hydration, surveillance and monitoring	Clothing, siesta
Storms and Floods	Planning laws (e.g. land use), building guidelines, ban precarious residential placements, economic incentives for building	Urban planning, storm shelters, construct strong seawalls, fortify sanitation systems	Early warning systems, disaster preparedness programmes, surveillance and monitoring	Use of storm shelters
Air quality	Emission controls, traffic restrictions, air quality standards	Improved public transport, catalytic converters, smokestacks	Pollution warning, surveillance and monitoring	Carpooling
Allergies	Planning laws (e.g. land use)		Early warning systems, surveillance, monitoring	Remain indoors
Water related diseases	Watershed protection laws, water quality regulation, enforce high standards of hygiene, greater access to (emergency) medical care	Improved water treatment, improved sanitation and water storage, screening of pathogens	Public education campaign, boil water alerts, early warning systems, surveillance and monitoring	Hygienic good practices behaviour, boil water
Food-related diseases (incl. Malnutrition)	Enforce high standards of hygiene, greater access to (emergency) medical care, access to international aid agencies and distribution networks	Improvements in food preparation and storage, screening of pathogens	Public education campaign, early warning systems, surveillance and monitoring	Hygienic good practices behaviour
Vector-born diseases	Vaccination programmes and enforce vaccination laws, greater access to (emergency) medical care	Vector control, vaccination, impregnated bednets, install window screens, habitat control	Public education campaign, surveillance and monitoring	Use of impregnated bednets, window screens, and tropical insect repellents, water storage practices, self inspection (for Lyme disease)

Adopted from the cCASHh website and McMichael & Githeko (2001).

Much can be gained through preventative healthcare, such as improved knowledge combined with financial incentives that result in adaptive behaviour. Special attention has to be paid to vulnerable sub-groups. The group of stakeholders largely disagreed, however, about the question whether or not the adaptation strategies could be realised with limited extra investments or not (Box 4.1) (Van Ierland, De Groot et al., 2001).

Box 4.1: Costs of adaptation strategies (van Ierland et al., 2001).

Can the Dutch population reduce the health effects of climate change with limited extra investments? Opinions about this topic differed greatly within a group of Dutch stakeholders, which is illustrated by their comments:

- Investments are relatively small in comparison with other countries and other sectors in the Netherlands;
- Globalisation also requires investment elsewhere;
- We will have to put money in education. Dependent on this we will have to decide whether extra investments are necessary;
- In a well devolved health care system, relatively not much extra has to be invested to cope with the expected effects;
- Extra investments in the up-levelling of dikes and coastal works seem necessary;
- It will cost much extra, for example the up levelling of dikes and drinking water supply.

Adaptive measures directed to health could also have impacts on other sectors. Examples include (van Ierland et al., 2001):

- Air-conditioning influences energy consumption and air-quality);
- Reducing air pollution leads to constraints on transport;
- Infrastructure change may harm ecosystems in many areas;
- There could be some positive influence on hydrology and possibly ecosystems, for example if the water storing capacity of river zones are extended;
- Infrastructural adaptations and the up-levelling of dikes may have a negative effect on flora, fauna and ecosystems;
- Reclaiming wetlands to reduce the growth of contagious diseases would be disastrous for our vanishing wetlands;
- The promotion of reforestation and tree planting to reduce the CO_2 emissions may be useful in other areas, like the reduction of temperatures in urban areas, noise reduction and the control of the air quality;
- Positive effect of infrastructural measures to ensure the insurance options of risks (like the prohibition of house construction in the river foreland);
- Energy policy less based on fossil fuels (to reduce air pollution), also in the transport sector, may possibly lead to a greater efficiency in using more clean production systems, which can only be favourable for the sectors themselves.

4.5.2 Indicators and thresholds

Policy measures are necessary when health risks are considered to be undesired or unacceptable. 'Health risk' is generally taken to be the probability of injury, disease or death under specific circumstances (Hunter & Fewtrell, 2001). Subsequently, the acceptable health risk concerns the accepted level of this probability. In Dutch environmental policy, the chance of death is the dominant factor in establishing standards. With regard to hazardous substances without a threshold (e.g. carcinogens) the Maximum Permissible Risk (MPR) of dying is one in a million per year, while for substances with a threshold value (a value below which effects are unlikely to occur) the MPR is the same as the health-based advisory guidelines (RIVM, 2001). In the UK, the Health and Safety Executive also defines acceptable health risks in terms the annual risk of dying (Table 4.6) (RCEP, 1998).

One other definition of acceptable risk, which is widely accepted in environmental regulations, is if lifetime exposure to a substance increases an individual's chance of developing cancer is one in a million or less (this has become a sort of golden standard) (Hunter & Fewtrell, 2001). The US Environmental Protection Agency and the World Health Organization (WHO) also both use the lifetime risk of becoming ill in order to set standards for carcinogen concentration in drinking water (Table 4.6) (Cotruvo, 1988; WHO, 1993).

Table 4.6 Established acceptable health risks with regard to harmful substances.

Country/Institution	Established acceptable health risk with regard to harmful substances
Netherlands	MPR* carcinogens: annual risk of dying of 10^{-6} (one in a million) MPR non-carcinogens: according to health-based advisory guidelines (RIVM 2001).
USA (Environmental Protection Agency)	Target reference risk range for carcinogens in drinking water: lifetime risk of developing cancer between 10^{-4} (one in 10,000) and 10^{-6} (one in a million) (Cotruvo 1988).
UK (Health and Safety Executive)	Acceptable risk at which no further improvement in safety is needed: annual risk of dying of 10^{-6} (RCEP 1998).
World Health Organization	Guideline for carcinogens in drinking water: lifetime risk of developing cancer of 10^{-5} (WHO 1993).

* MPR= Maximum Permissible Risk.

Another sensible approach would be to consider accepted health impacts in terms of the total disease burden of a population and to define the acceptability in terms of falling below an arbitrary defined level. However, in reality some difficulties might arise when adopting this approach (Hunter & Fewtrell 2001). The public based approach towards accepted health risks is based on what is acceptable to the general public. Perceived risks often do not agree with factual/scientific risks assessments. Bennet (1999) identified several 'fright factors' that influence the public's concern about risks and the public's risk acceptance (Box 4.2). In addition, acceptable health risk can also be defined using an economic approach (Hunter & Fewtrell 2001). In The Netherlands, the need to include economic consequences in health risks assessments is recognized (RIVM, 2001).

Based on the above, one can conclude that, in establishing the acceptable health risk of climate change, several approaches are possible:

- To determine the maximum acceptable risk of dying due to climate change;
- To determine the maximum acceptable risk on morbidity due to climate change;
- To determine the maximum acceptable burden of disease level attributable to climate change;
- To survey public acceptance of the health risk associated with climate change (public-based approach);
- To assess which climate change related health risk is acceptable from an economic perspective.

Box 4.2: Fright factors (Bennet, 1999)

Risks are deemed to be less accepted if they are perceived to be:

- Involuntary;
- Inequitably distributed in society;
- Inescapable, even if taking personal precautions;
- Unfamiliar or novel;
- Man-made rather than natural;
- The cause of hidden and irreversible damage which may result in disease many years after;
- Of particular threat to future generations, for example by affecting small children or pregnant women;
- The cause of a particular dreadful illness or death;
- Poorly understood by science;
- The cause of damage to identifiable, rather than anonymous individuals;
- Subject to contradictory statements from responsible source.

Table 4.7 gives an overview of possible acceptable risk levels with regard to the health impacts of climate change. These can be viewed as normative threshold levels of climate change induced heat stress, allergic disorders or infectious diseases (e.g. Lyme disease).

Table 4.7 Possible acceptable risk levels with regard to the health impacts of climate change.

Approach	Possible accepted health risk levels
Acceptable annual risk of dying	One in a million (10^{-6}) or equal to zero.*
Acceptable lifetime risk on morbidity	Information not available; accepted risk depends on the nature of disease but is likely to be higher than one in a million (10^{-6}) for diseases less severe than cancer (e.g. allergies).
Acceptable burden of disease level	Information not available.
Public acceptance	Information not available, but health risks deemed to be less accepted due to nature of climate change problem.**
Economically defined acceptable risk	"Any risk where the costs of reducing that risk exceeds the financial and utility benefits that would arise from that reduction and where such resources required in this risk reduction would not be better spent on other public health issues" (Hunter and Fewtrell 2001).

* Based on Dutch policy.

** The climate change is likely to be perceived as, for example, involuntary, unfamiliar, man-made, the cause of hidden and irreversible damage, poorly understood by science (due to scientific uncertainties) and inequitably distributed in society.

4.6 Tourism and recreation

4.6.1 Adaptation options

The projected changes in climatic conditions between and within seasons would have profound impacts on the profitability of the tourist sectors, and on travel patterns across Europe. A participatory study revealed that stakeholders expect the main changes for the Netherlands to occur in recreation and daytrips rather than incoming tourism (van Ierland et al., 2001). Although tourists and recreationists often behave similarly (Wall, 1998), there are marked differences in their decision-making processes. Recreationists can respond to the weather conditions on very short notice (IISD, 1997) and quickly adjust their plans. In contrast tourists spend at least one night outside their usual place of residence, according to common definitions of what constitutes a tourist. Therefore, tourists depend on planning for the medium term. Wall (1998) therefore hypothesises that domestic tourist and recreational patterns are more stable than international ones and that remote destinations are more vulnerable than destinations in the proximity of metropolitan areas.

Tourists, in their turn, are more footloose than for example hotel owners. Most of them have no long-term commitment to certain tourist destinations or activities, which makes it relatively easy to substitute one destination for another, or one activity for another. Research from the United Kingdom suggests that people's holiday planning becomes more spontaneous as temperature and the amount of sunshine increase (Giles & Perry, 1998). Instead of booking a trip to more sunny resorts early in the season, people postpone their decisions until later in the season to see how the weather conditions develop at home. This would further increase the significance of last-minute trips.

Tour operators tend to be quite flexible as well; their planning horizon is typically limited to a few years. They will shift their portfolio from 'losing' regions to 'winning' regions whose climatic conditions improve. Other segments of the tourist industry, such as hotels and other tourist facilities, are tied to a particular area: invested capital is high and so are 'sunk costs' that cannot be easily recovered in the short term (Wall, 1998). Large-scale infrastructure such as ports, airports and highways are built with even longer time horizons in mind: at least several decades. The higher the sunk costs, the more adaptation is restricted to making the best of the situation instead of just moving to another place.

The spatially constrained tourist industry can respond to increased heat and smog by supplying improved air conditioning in tourist accommodation and by developing additional indoor attractions. In addition, changing seasonal patterns may trigger operational changes. An extended and flattened season in the Netherlands, for example, may allow for a more efficient use of facilities and resources.

The Alpine countries are investigating options for adaptation to their decreasing snow reliability (Bürki et al., 2003). A technical innovation is the use of artificial snow, but this technique is expensive and energy-intensive. More importantly, it is only effective at below zero temperatures, i.e. the technique can solve the problem of lacking snowfall, but it does not solve the problem of rising temperatures. Another option is to close the low-lying ski resorts and open new ones at higher altitudes. This, however, is very expensive and it leads to an even greater spatial concentration of winter sports. A third option is the diversification of Alpine tourism, by developing non-snow-related activities and attractions or by constructing indoor ski pistes.

In the Netherlands and elsewhere, it is common practice to counter beach erosion by beach recharge operations. Climate change will force the frequency of these operations to be increased, which is costly but technically feasible. The option of withdrawing the coastline may be a theoretical possibility, but will entail prohibitive costs. Countries around the Mediterranean may adjust to the rising sea level by lifting infrastructure and facilities, such as entire marinas.

The sustainability of water supply may prove to be a major factor determining the long-term viability of tourism on Majorca and in many other parts of the Mediterranean and Europe as a whole. Desalination, water importation and conservation measures have been tried with only limited success so far. Other alternatives, such as rationing and much higher charges may provide other solutions, but cannot be implemented without direct negative impacts on the key industries of tourism (Kent et al., 2002).

4.6.2 Indicators and thresholds

Tourism is a social phenomenon. The human factor tends to reduce the relevance of absolute critical thresholds. For example, northern Europeans travel to the Spanish coasts, because the summer climate over there is *more pleasant than* at home, not necessarily because the Spanish climate is perfectly pleasant in any absolute sense.

The effects that climate change may have on travel patterns should therefore be studied for Europe or the world as a whole. As a result, the identification of absolute climate thresholds in relation to tourist behaviour tends is very difficult if not impossible. Indices such as the Tourism Comfort Index (TCI, see paragraph 3.6.2) are promising tools, but to date, only limited validation against arrival data has been performed. Preliminary analyses for Majorca suggest that TCI scores exceeding 75 are required for beach tourism (Amelung, submitted). If this threshold were generally valid, the Netherlands could become a destination for beach holidays if global temperature would rise by around 2.5 degrees Celsius (equivalent to the 2050s in the A1F scenario). For the time being, however, this result remains largely speculative.

Thresholds for the tourist industry are almost entirely economic in nature. If turnover is not enough to cover costs, businesses go bankrupt. Economic performance depends directly on tourist behaviour and is only indirectly related to climatic conditions. It is therefore difficult to express the economic thresholds in climatic terms.

Considerable work has been done on snow reliability in the Alps, a prominent destination for Dutch winter sports enthusiasts. According to Bürki et al. (2003), the number of snow reliable ski resorts in Switzerland will drop significantly as a result of climate change (see Table 4.8). The present snow line is likely to rise by 200 to 300 metres over the next 30 to 50 years. In scenarios with more rapid climate change, a shift to 1800 metres cannot be excluded.

Results are even more dramatic for Austria and Italy, since the mountain areas in these countries are lower lying. Many mountain villages, above all in the central and eastern parts of Austria, will lose their winter industry because of climate change (Bürki et al., 2003). Some recreational and tourist activities transcend mere economic and social relevance: they are crucial for countries' national identities. For the Netherlands, the *Elfstedentocht* (a skating event) is of significant national and cultural importance. People may simply be opposed to losing the *Elfstedentocht* as a regular event, e.g. once every ten years. The location of such as threshold, however, can only be determined through a political process.

Table 4.8 Snow-reliability of Swiss ski resorts.

Region	Number of ski resorts	1200 metres above sea level		Snow-reliability 1500 metres above sea level		1800 metres above sea level	
		No.	%	No.	%	No.	%
Jura	15	4	27	1	7	0	0
Alps (Vaud + Frib.)	19	16	84	7	37	4	21
Valais	54	54	100	52	96	40	74
Bern (ex. Jura)	35	30	86	20	57	12	34
Central Switzerland	35	26	74	13	37	7	20
Ticino	8	8	100	3	38	2	25
Eastern Switzerland	18	11	61	6	33	3	17
Grisons	46	46	100	42	91	33	72
Switzerland	230	195	85	144	63	101	44

Source: Bürki et al., 2003.

4.7 Coastal zone management

4.7.1 Adaptation options.

The coastal zone is a dynamic system characterised by a range of physical- and socio-economic processes at different spatial and temporal scales. Short-term fluctuations, to a large extent interact with long-term trends. The dynamic character of the system is crucial when considering impacts of climate change and adaptation options of the coastal zone.

Impacts and responses are, in fact, interdependent. In first instance, the *magnitude* of changes in driving processes (drivers) and in boundary conditions (pressures) determines the *potential* impact. Then, however, the response of the system by natural- and socio-economic adaptation processes, will determine the *actual* impact. The system response is largely depending on the *rate* of external changes. This is the background to the argument in Section 4.7 that the main indicator for climate change impacts on the coastal zone is the *rate of sea-level rise*.

The response may be different for different subsystems of the coastal zone. For example, the critical level of sea-level rise for tidal marshes in the Wadden Sea area is estimated to approximate 8.5 mm/year; for tidal flats in larger tidal basins to 3 mm/year, and in small tidal basins to 6 mm/year (van Goor, 2003).

In this respect it is important to consider that several processes each have their own typical timescale, determining the time scale of response. Table 4.9 presents an overview:

Table 4.9 Response time scales of coastal zone impacts.

	Process	Response time scales
Hydraulic phenomena	Wave/storm-climate,	Immediate
	Sea-level rise	Centuries
Morphology	Sedimentation patterns,	Decades
	Coastal erosion	Immediate
	Coastal retreat	Decades
Ecology (terrestrial and marine)	Species	Immediate
	Ecosystems	Years
Many aspects of human use	Safety,	Years
	Short term socio-economic developments	Years (when local activities need to be rearranged)
	Long term socio-economic developments	Decades (when areas of national interest and scale need to be re-arranged)

An illustration of potential responses and of adaptation options to climate change, involving both natural- and socio-economic processes, is presented by the European Commission (2004) in a EUROSION-report on sustainability of coastal zones:

- Recommendation 1: Restoring the sediment balance and providing space for coastal processes: A more strategic and proactive approach to coastal erosion is needed for the sustainable development of vulnerable coastal zones and the conservation of coastal biodiversity. In light of climate change it is recommended that coastal resilience is enhanced by (a) restoring the sediment balance; (b) allocating space necessary to accommodate natural erosion and coastal sediment processes; and (c) the designation of strategic sediment reservoirs.
- Recommendation 2: Internalise coastal erosion cost and risk in planning and investment decisions: The impact, cost and risk of human induced coastal erosion should be controlled through better internalisation of coastal erosion concerns in planning and investment decisions. Public responsibility for coastal erosion risk should be limited and an appropriate part of the risk should be transferred to direct beneficiaries and investors. Environmental assessment instruments should be applied to achieve this. Risks should be monitored and mapped, evaluated and incorporated into planning and investment policies;
- Recommendation 3: Make responses to coastal erosion accountable: Coastal erosion management should move away from piecemeal solutions to a planned approach based upon accountability principles, by optimising investment costs against values at risk, increasing social acceptability of actions, and keeping options open for the future. This move should be driven by the need to restore the coastal resilience and the favourable sediment status and be supported by Coastal Sediment Management Plans (CSMPs);
- Recommendation 4: Strengthen the knowledge base of coastal erosion management and planning: The knowledge base of coastal erosion management and planning should be strengthened through the development of information management strategies. These should include dissemination of 'best practice' (what works and what

does not), provide a proactive approach to data and information management and promote institutional leadership at the regional levels.

4.7.2 Indicators and thresholds

Feasibility of the adaptation options is depending on the magnitude and rate of climate induced sea-level rise, and on the adaptation capacity. As indicated above, the adaptation capacity may differ for different subsystems of the coastal zone. Thresholds or critical levels of sea-level rise are related to the adaptation capacity.

Notwithstanding the fact that the adaptation capacity is dominantly depending on the *rate* of changes, qualitative thresholds of *absolute* values of sea-level rise have been estimated on the basis of expert judgement for the social-, economic- and ecological subsystems of the coastal zone (Table 4.10):

Table 4.10 Threshold levels and values of absolute sea-level rise.

Threshold level	Threshold values of absolute sea-level rise (m) per subsystem of the coastal zone		
	Social	Ecological	Economic
No problem	Up to 0.5 m	Up to 0.5 m	Up to 0.5 m
Significant effects	0.5 – 2 m	0.5 – 1 m	0.5 – 4 m
Irreversible effects	More than 2 m	More than 1 m	More than 4 m
Comments:	*All values refer to "average global response"*		
	Protection activities have more and more impact on spatial planning and coastal (fishery) communities. Resettlement becomes an attractive alternative.	Coastal ecology is more and more subject to "hard" protection measures (no tidal flats and marshes anymore) and coral reeves will drown.	Protection activities become too expensive in construction and maintenance, so that re-settlement of the majority of the coastal communities needs to take place. Valuable land and infrastructure is lost.

4.8 Summing up the adaptation options

This chapter shows that adaptation options are not easy to define in precise terms, due to the uncertainties in the climate change processes, in particular at the mid- and longer term. Below, we will discuss the main adaptation options for the aspects examined in the study. For ecosystems, there are two types of adaptation options. These are: (i) measures aimed at creating conditions under which species have sufficient possibilities to adapt; and (ii) measures aimed at reducing other threats to ecosystems (such as disturbance, acidification, overexploitation). Specific measures include the creation of space for ecosystems, e.g. through ecological networks such as the Ecological Main Structure in the Netherlands.

On the same basis, estimates of thresholds of sea-level rise *rates* are given in Table 4.11.

Table 4.11 Threshold levels and value of sea-level rise rates.

Threshold level	Threshold values of sea-level rise rates (mm/year) per subsystem of the coastal zone		
	Social	Ecological	Economic
No problem	Up to 3 mm/year	Up to 3 mm/year	2 mm/year
Significant effects	3-10 mm/year	3-6 mm/year	2-10mm/year
Irreversible effects	More than 10 mm/year	More than 6 mm/year	More than 10 mm/year
Comments:	All values refer to "average global response" The impacts strongly depend how the local social, ecological and economic systems are able to adapt to the changing sea level. When these systems cannot follow the sea-level rise, strong and immediate action is finally required.		
	Coastal (fishery) communities and economies are endangered by more severe coastal erosion.	This holds for coastal systems were, initially, enough sediment is available to follow the sea-level rise.	Budget for construction and maintenance of protection works is gradually more likely to exceed costs for resettlement.

However, as climate change induced disturbance acts jointly with other disturbances, it is also important to consider the option of reducing other disturbances, such as recreation, land use conversion, disturbance, etc.

For food supply, the main impacts may be located in Australia and Africa. They are related to changes in precipitation that could enhance droughts, as well as increased impacts of extreme events, besides drought in particular also floods and storms. Whereas Southern Europe is most vulnerable to droughts, floods are particularly relevant to the Netherlands and parts of Germany and France. Adaptation options include changes in crop choice, water management, reclamation of land, research programs and organisation structure. Some farm level adaptation strategies, such as changes in planting and harvest dates, crop rotation and crop varieties, can be incorporated without large changes in management practises. However, longer term planning is required to stimulate research on drought tolerant crops, enhanced irrigation techniques and other adaptation techniques.

Adaptation of the water sector requires a substantial number of investments in water control techniques including sluices and pumping stations. Specific adaptation options depend upon the specific characteristics of rivers and lakes. For instance, for the Rhine and Meuse, a number of measures are currently considered that aim to deal with an increase of the design discharge of the Rhine up to 18.000 m^3/s and the Meuse of 4600 m^3/s for the end of this century.

Regarding health, populations with a low adaptive capacity are more vulnerable to the health effects of climate change than populations with a higher ability to adapt. Possible adaptation strategies to mitigate the health effects of climate change cover a wide spectrum. A simple example is that of reducing the extra deaths and episodes of serious illness experienced by urban populations during extremes of heat. Adaptations could include ‘weather-watch’ warning systems, better housing design, climate-related urban planning (to reduce the ‘heat island effect’), and greater access to emergency medical care. The success of adaptation strategies will rely on economic factors, as well as the involvement of local and national communities in the decision-making process. Dutch stakeholders (e.g. health professionals, policymakers, interest groups, scientists) feel that the Netherlands will be capable of coping with possible health effects resulting from climate change. Possible measures that they frequently mentioned to reduce the impacts included education and monitoring. Much can be gained through preventative healthcare, such as improved knowledge combined with financial incentives that result in adaptive behaviour. However, special attention has to be paid to vulnerable sub-groups.

As for the tourist sector, the projected changes in climatic conditions between and within seasons would have profound impacts on the profitability of the sectors, and on travel patterns across Europe. A participatory study revealed that stakeholders expect the main changes for the Netherlands to occur in recreation and daytrips rather than incoming tourism. Adaptation will take place in terms of travel patters of tourists. For instance, they will wait longer to check climatic conditions before they decide if and where to go. In addition, technical options are able to partly adapt to a changing climate. For instance, the Alpine countries are investigating options for adaptation to their decreasing snow reliability.

The coastal zone is a dynamic system characterised by a range of physical- and socio-economic processes at different spatial and temporal scales. The dynamic character of the system is crucial when considering impacts of climate change and adaptation options of the coastal zone. The system response is largely depending on the rate of external changes. The main indicator for climate change impacts on the coastal zone is the rate of sea-level rise. Adaptation is required, in particular, to the maintenance of the shore-line and the decrease of coastal erosion rates. A strategic and proactive approach to coastal erosion is needed for the sustainable development of vulnerable coastal zones and the conservation of coastal biodiversity.

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5. Climate change thresholds and implications for GHG emissions

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5.1 Introduction

This chapter explores the implications for allowable levels of GHG emissions on the long and short term of setting long-term policy targets for (the impacts of) climate change. The point of departure of our analysis will be the present long-term climate targets of the Netherlands (see Chapter 1). However, we will also evaluate the implications of other possible impact threshold levels

In order to determine allowable levels of GHG emissions we have to back-calculate from acceptable levels of climate change to emissions (Figure 5.1). This is not simple because there are major uncertainties in the cause-effect chain - the relationship between levels of GHG emissions and the impacts related to the human-induced climate change -, particularly on a regional scale.

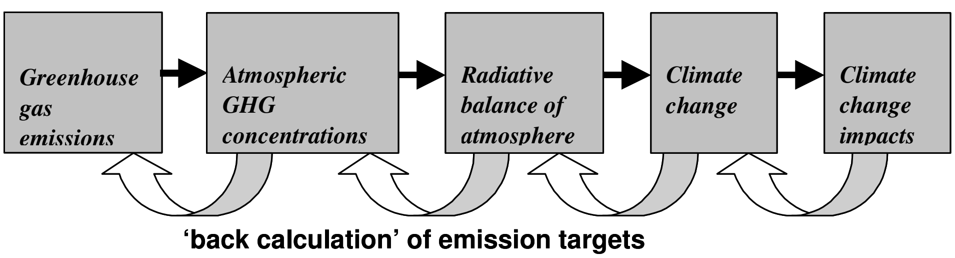

Figure 5.1 Cause-effect chain of climate change.

For some key parameters, like the increase in atmospheric concentrations resulting from emissions of GHGs or the (resulting) increase in global average surface temperature, there are estimates of the levels of uncertainty and even of the probability distribution of parameter values. In other cases, like the change in climate in some regions at the local level, we are not even sure about the direction of the changes, as different models show different outcomes. Moreover, uncertainties accumulate along the causal chain. This is the major problem in relating indicator threshold values for "dangerous climate change" to levels of allowable GHG emissions for the long- and short term.

Two different approaches can be used:

- The first is a simple deterministic approach where we indicate the possible levels of climate change on a global level that may result from stabilizing GHG concentrations at different levels in the atmosphere and related emission pathways over this century that would be required. This will be mainly based on the Global Reduction Pathways

(GRP) study for the European Commissions (Criqui et al., 2003: Eickhout et al., 2003);

- The second approach is a probabilistic approach to target setting (Mastrandea & Schneider, 2004: Webster et al., 2003). This approach intends to deal with the uncertainties in the cause-effect chain in a more quantitative way by saying something about the likelihood of meeting different long-term targets when stabilizing the GHG concentrations at different levels. We will use this approach to say something about the likelihood of avoiding crossing threshold levels for indicators of dangerous climate change, identified in the other chapters. This first requires an assessment of the relationship between local versus global indicators of climate change.

5.2 Local versus global climate change indicator levels

The assessments in the previous chapters have defined impact levels and thresholds at many different locations and spatial scales. To assess the implications of these thresholds for defining global climate-change targets, one needs to link the local threshold values to global indicators for climate change. In particular, we want to know the ratio between local temperature change and global average surface temperature increase.

General Circulation Models (GCMs) are arguably the best available tools to project spatial patterns of climate change indicators. However, given the large uncertainties in particularly regional projections of climate change it seems most appropriate to draw information from a suite of GCMs, instead of just using one model. In Figure 5.2a, we show the annual-mean ratio of local over global temperature change, averaged over 17 GCMs. In these GCM experiments only GHG concentration changes were used in the projections, excluding the contribution of changes in aerosols. The patterns resulting from aerosol changes increase overall uncertainty, but it can be expected that their contribution to climate change in the long term will strongly decrease due to air pollution policies (See also Chapter 2). For constructing Figure 5.2, we have used the SCENGEN modelling tool (Hare, 2003: Hulme et al., 1995).

On the large scale, the response of the near-surface air temperature[20] is stronger for continental areas than for the oceans, as well as for higher latitudes compared to the tropics. Over Europe, the mean ratio is 1.3ºC, with an inter-model spread (standard deviation) of 0.2ºC. For the marine climate of The Netherlands this ratio is projected lower as 1.1ºC, with standard deviation 0.2ºC. The heterogeneity, or spread in results between the GCMs can be expressed by the inter-model standard deviation as in the examples for Europe and the Netherlands. However, the signal-to-noise ratio, defined here as the mean ratio divided by the inter-model standard deviation, might be more useful. As shown in Figure 5.2b, over the North Atlantic Ocean the uncertainties in the response appear to be relatively high (low signal-to-noise-ratio). This is mainly caused by the uncertainties in the response of the ocean circulation, which is particularly high in the northern North-Atlantic. The ratios shown in Figure 5.2a can be used for relating the local impact indicators to the global indicators. An important caveat in this method of averaging GCM pattern projections is that the GCM results do not provide a randomly distributed sample.

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[20] From here on simply referred to as temperature change.

Some GCMs are more advanced than others. In addition, model parts of different GCMs might be related. For the analysis at hand however, the average over many model results is a better starting point than selecting only one model.

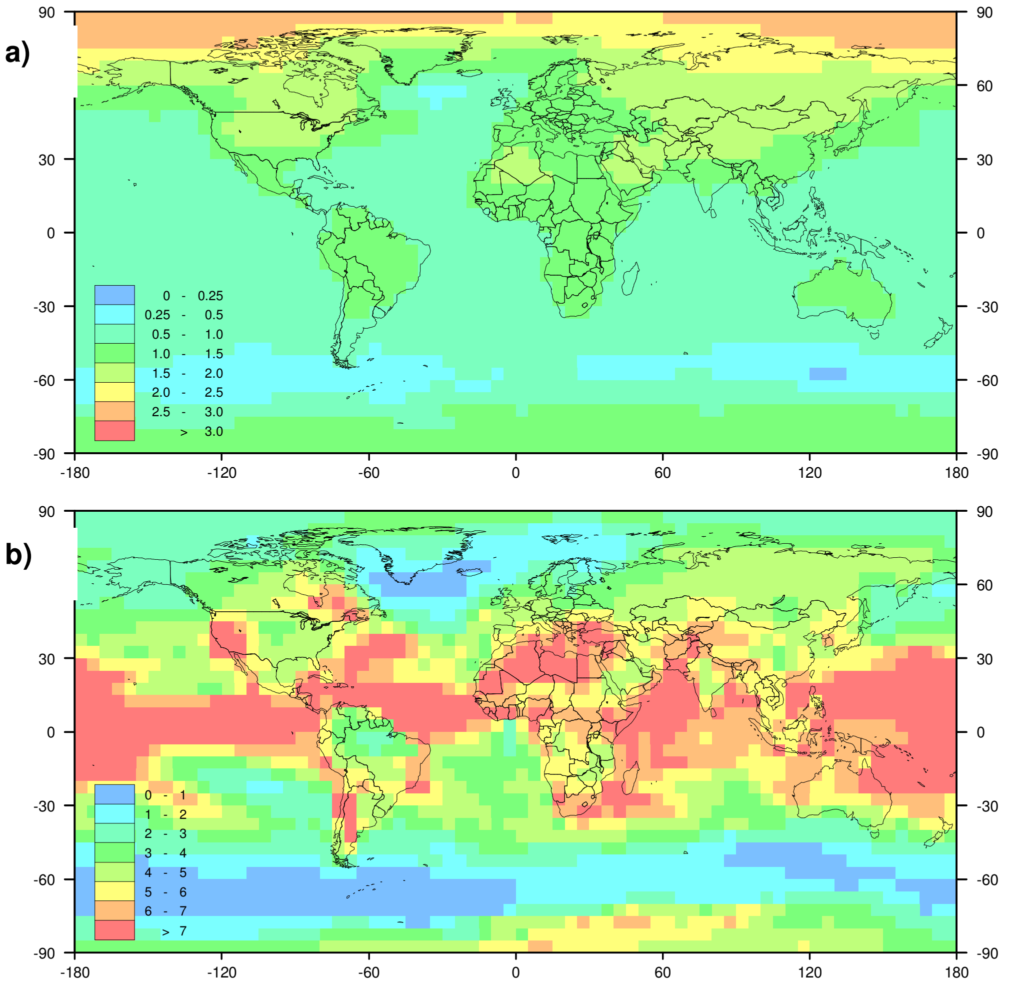

Figure 5.2 Ratio of local over global annual-mean temperature change averaged over 17 GCMs (ºC/ºC, top panel (a)) and inter-model signal-to-noise ratio (lower panel (b)).

5.3 Climate change indicator levels and levels of GHG concentrations

In order to deduce emission targets from global long-term climate targets, such as the Netherlands' and EU 2 ºC temperature target, it is first necessary to relate the climate targets to levels of GHG concentrations in the atmosphere.

The Climate Convention aims to stabilize GHG concentrations (See Chapter 1). It should be noted that stabilization of the GHG concentrations will not stop further climate change immediately after the point in time when stabilization is reached ('warming commitment'), due to inertia in the climate system. There will not yet be an equilibrium in the climate system, in particular between the atmosphere and the oceans. Thus temperatures will still (slowly) increase for decades to centuries, while sea-level rise will continue for centuries to millennia (see Chapter 2). Especially for high stabilization levels, it is not likely that concentrations will remain constant for millennia, the time period needed to reach the equilibrium climate system. In that sense using GHG stabilization profiles is a hypothetical exercise. In time-dependent model experiments, it has been shown that in general only about 70% of the equilibrium temperature is reached at the time that concentrations are stabilized and only 10% of the equilibrium sea-level rise (Webster et al., 2003). Stabilizing the temperature increase soon after concentrations reach their stabilization target level would thus require that after this point in time the concentrations would decrease again, even more so if the aim were to stabilize sea-level rise. The advantage then is of course that temperature change and sea-level rise would stay far below the equilibrium value.

Nevertheless many studies focused on stabilization of GHG concentrations assume these to remain at constant levels after stabilization. Moreover, until recently most studies only focused on one GHG only: CO_2. However, while CO_2 is the most important GHG, other gases presently contribute about 1/3 to the enhanced greenhouse effect (IPCC, 2001). The IPCC in its Third Assessment Report (TAR) has included the contribution of other GHGs in stabilization scenarios, but in an unsatisfying way. By assuming that these non-CO_2 gases remain unabated, the temperature increase from stabilizing CO_2 concentration is overestimated, particularly for the lower stabilization levels (see Box 5.1).

Here, we will take the contribution of the various GHGs into account by using the concept of CO_2-equivalent concentrations (CO_2-eq., Box 5.1). This climate metric includes the climate impact of all (Kyoto) GHGs (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) together, expressed as the hypothetical level of the CO_2 concentration that would have an equal impact on the radiative balance of the atmosphere (the energy balance between incoming sunlight and outgoing heat radiation). The climate metrics discussed here only relate to these Kyoto GHGs and leave out the contribution of other GHGs (i.e. CFCs, HFCs) and radiative active components such as aerosols, and other ozone precursors. Still, this leads to some complications when calculating time-dependent concentration and emission pathways, because of the variation in the time period that different GHGs remain in the atmosphere.

What levels of temperature and sea-level rise results from what level of CO_2-eq. concentrations? In order to answer this question we need to look at the climate sensitivity (CS) of the climate system. This is the equilibrium global average surface temperature increase resulting from a doubling of the CO_2 (equivalent) concentrations in the atmosphere compared to pre-industrial levels (see Box 5.1) The value of this parameter is not well known. Since its First Assessment Report in 1992, the IPCC estimates its value between 1.5 and 4.5 ºC, with a “best guess” value of 2.5 ºC (IPCC WG1, 2001).

Figure 5.3 shows that for a climate sensitivity of 2.5 ºC, CO_2-eq. concentrations need to be stabilized at 550 ppmv to limit the global-mean equilibrium temperature to 2 ºC. This result is very much dependent on the CS assumed. If the CS would be lower than 2.5 ºC GHG concentrations could be stabilized at a higher level; if the CS would be higher GHG concentrations would have to be stabilized at a lower level.

Again, note that by reducing emissions further after stabilization of concentrations, the temperature change can be limited to significantly less than the equilibrium target in Figure 5.3.

In line with these results, Eickhout et al. (2003), using the IMAGE-2.2 model in a time-dependent analysis, report that stabilizing the CO_2-eq. concentration at 550 ppmv will result in a maximum global mean temperature increase of less than 2 ºC in 2100 with a low to medium value for the climate sensitivity. In case the GHG concentrations are stabilized at 650 ppmv the temperature increase will only remain below 2 ºC if the value for the CS is at the low end of the IPCC range, and thus it is unlikely that the EU climate target will be met. With a high CS of 4.5 ºC, neither stabilization levels will meet the 2 ºC target. To some extent, these time-dependent results also depend on the climate model used. For example, for the MAGICC climate model, used later in this chapter, CO_2-eq. concentrations need to be stabilized at somewhat lower levels to achieve the same temperature targets.

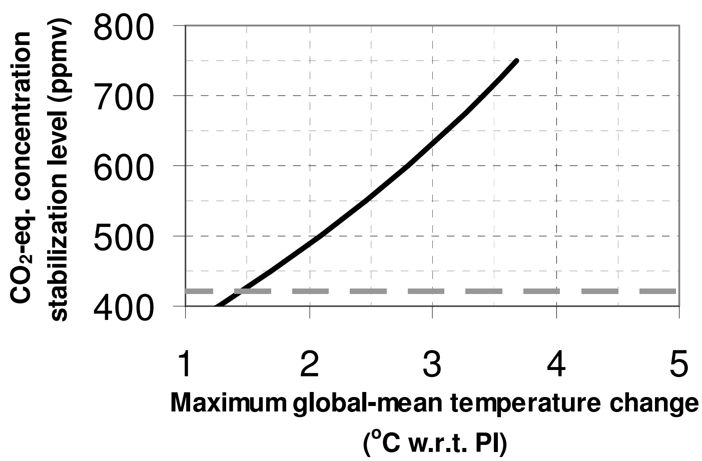

Figure 5.3 Stabilization levels of GHG concentration and resulting global averaged temperature increase in case of a climate sensitivity of 2.5 ºC.

Instead of these isolated statements depending on specific values of the CS, one would like to make more quantitative statements about the probability of meeting long-term climate targets for different levels of GHG concentrations. In recent years, there have been various studies estimating the likelihood of the CS to have a certain value (see Box 5.1). The results of these estimates are so-called probability density functions (PDFs). Figure 5.4 shows two examples of such PDFs, based on observational climate data of the last centuries). These examples illustrate that the range of possible values of the CS is wider than the IPCC range. They also show that the research methodology is still a source of significant uncertainty in the probability distribution of the values of the CS (See Box 5.1).

Box 5.1: Explanation of concepts and methods

CO_2-eq. Concentration. The concept of equivalent-CO_2 concentrations was developed as a simple tool to compare the climatic effects of different mixes of GHGs (Schimel et al., 1997). It has been applied, for example, in assessments of emission abatement for several GHGs, that limits future climate impacts in some (often cost-) optimal way. In general, the climatic effect of GHGs is measured as the disturbing influence on the atmosphere's radiative budget. Research in the last decades has identified a long list of GHGs with a positive contribution to global warming. The most important are included in the Kyoto Protocol ('Kyoto gases'), although others, like many gases included in the Montreal Protocol, make a considerable contribution. Most gases stay long enough in the atmosphere to become distributed spatially homogenous in the horizontal, like CO_2. Much more problematic is the inclusion of forcings by aerosols (negative and positive), because the effect of these is highly localised geographically. In our calculations, as in most cases, the total CO2-eq. concentration only concerns the Kyoto gases, but in other assessments other definitions might be used that may include aerosols. Obviously, it is more complicated to define emission scenarios for stabilizing CO_2-eq. concentrations than CO_2 only, because these can be reached by various combinations of gasses that also have different contributions to the radiative budget over time. Four ways of accounting the non-CO_2 emissions have been proposed: (i) simple scenario assumptions (e.g. using a common non-intervention scenario (SRES A1B) for non-CO_2 emissions: (Cubasch et al., 2001)), (ii) concentrations or radiative forcing for non-CO_2 are proportionally scaled with CO_2 (e.g. about 23% of CO_2 forcing: Raper et al.,1996, or a constant 100 ppmv is added to a CO_2-concentration stabilization target: Eickhout et al., 2003); (iii) accounting for source-specific reduction potentials for all gases (e.g. Morita, 2000: Swart et al., 2002) and (iv) cost-optimisation over the GHG emissions (Manne and Richels, 2001: van Vuuren et al., 2003). We use a scaling variant, which assumes that at lower CO_2 stabilization levels, efficient measures would involve stronger cuts on non-CO_2 emissions as well. In addition, at high CO_2 concentration, the radiative effect of CO_2 is weaker ('saturation effect'), thus the same concentration of non-CO_2 gases adds more to the total CO_2-eq. concentration than at low CO_2 levels. A recent cost-optimised assessment suggests roughly an extra 50 ppmv non-CO_2 contribution at a CO_2-stabilization level of 350 ppmv, increasing to 150 ppmv non-CO_2 at 650 ppmv CO_2 (van Vuuren et al., 2003).

Calculating CO_2-eq. Concentration Targets. The simplest way to calculate the allowed level of CO_2-eq. concentration stabilization from a long-term equilibrium temperature target is to use the relation $dQ_{stab} = dQ_{2xCO_2} \cdot \frac{dT_{stab}}{dT_{2xCO_2}}$. Here, dT_{2xCO_2} is the climate sensitivity, dT_{stab} the global temperature target and dQ_{stab} the radiative forcing associated with a GHG stabilization target. dQ_{2xCO_2} is the radiative forcing at two times the pre-industrial CO_2 concentration. To calculate the CO_2-equivalent concentration target pCO_2eq_{stab} from dQ_{stab}, we use the inverse of the third formulation relating radiative forcing to CO_2 concentration from IPCC (2001): $pCO_2eq_{stab} = f^{-1}_{TAR3}(dQ_{stab})$. In more complex methods climate-modeling tools are needed.

Probability Estimates of Climate Sensitivity. In recent years, various attempts have been made to constrain the uncertainty in climate sensitivity, either through analysis of General Circulation Model results (Cess et al., 1989: IPCC, 2001: Raper et al., 2002), subjective expert judgments (Arrhenius, 1896: Morgan & Keith, 1995), consistency analysis based on palaeoclimatic data (Alley, 2003: Barron et al., 1995: Covey et al., 1996: Cuffey and Brrok, 2000: Hoffert & Covey, 1992), or based on more recent climate observations (Andronova & Schlesinger, 2001: Forest et al., 2002: Gregory et al., 2002: Harvey and Kaufmann, 2002: Knutti et al., 2002). The latter set of studies was not yet able to significantly constrain the climate sensitivity; indeed, values of up to 10°C cannot be excluded. Palaeoclimatic studies suggest generally lower and more constrained uncertainty ranges – however, today's climate feedback processes are different from those under palaeoclimatic conditions, thereby limiting the applicability of results. In this chapter, two different probability density functions (PDFs) for climate sensitivity are used (see Figure 6.4), drawn directly from the more sophisticated recent studies. Firstly, Forest et al. (2002) provide an example of an observationally based estimate, in which higher values have been more constrained by using an expert-prior PDF. Secondly, the results of Andronova and Schlesinger (2001) form an example of a PDF that puts little constraints on higher climate sensitivities. In our calculations, we use the cumulative density function (CDF), which gives the probability at value *X* that the CS has a value of *X*, or less. The CDF at value *X* is calculated by integrating the PDF from zero to *X*, in other words, calculating from the PDF the total probability of CS values of *X* and lower.

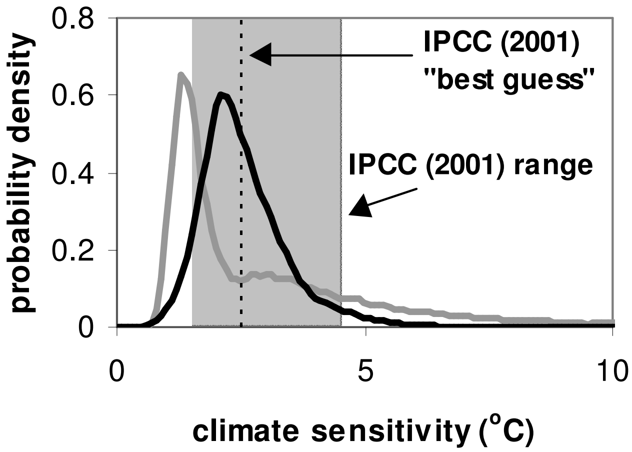

Figure 5.4 Probability Distribution Function of climate sensitivity.

Source: Forest et al. (2002) expert analysis (black) and Andronova and Schlesinger (2001) (grey).The grey area indicates the IPCC range, with the dotted vertical line depicting the "best guess value" of 2.5°C.

The estimates of the CS probability distribution can be used to give an indication of the likelihood that certain global average temperature targets (or targets for sea-level rise) will be met for different levels of stabilizing GHG concentrations. This is important, because policy makers and society may require different levels of certainty for different types of risks. The certainty required for avoiding irreversible and catastrophic climate change impacts resulting from events, such as a full collapse of the thermohaline circulation (THC), may be much higher than for preventing other negative climate change impacts, such as a regional loss of agriculture production.

This can be done by first making cumulative density functions (CDFs; see Box 5.1), accumulating the probability of the CS to be below a certain value. Next, since a specific combination of concentration and temperature target implies a certain value of the CS, these can be used to indicate the likelihood of meeting a certain global-mean temperature target for various levels of stabilization of GHG concentrations. Figure 5.5 shows the probability levels of achieving temperature targets for the two PDFs discussed above. For a stabilization at 550 ppmv CO_2-eq. the probability of limiting temperature increase to 2 ºC is about 33% (left panel) and 50% (right panel), respectively. For stabilization at 650 ppmv these values decrease to less than 10%, resp. 33%. A 100% probability is unachievable, because of the uncertainty in probability estimates, but also because of other uncertainties in the climate change cause-and-effect chain. An important observation from Figure 5.5 is that the probabilities depend non-linearly on concentration levels. For the 2ºC target in Figure 5.5, the probability of achieving this target increases more rapidly with decreasing concentrations at medium-to-low stabilization levels (coloured arrows).

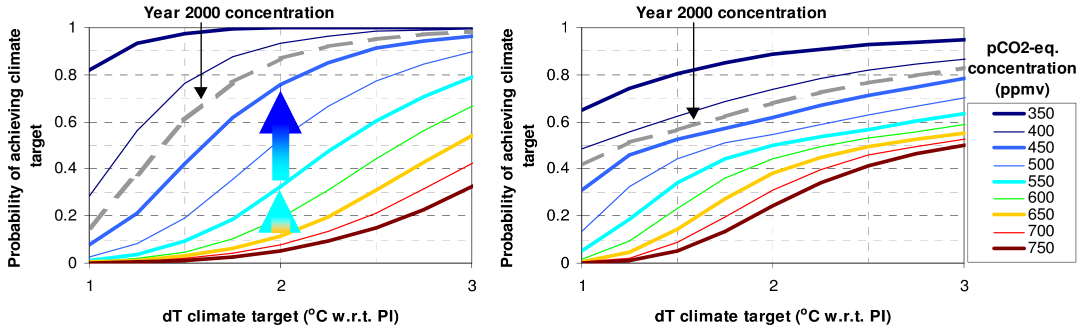

Figure 5.5 Probability of achieving a temperature target for a range of CO_2-eq. stabilization levels.

Note: This is implied by the probability distributions for climate sensitivity of Forest et al. (2002) (left panel) and Andronova and Schlesinger (2001) (right panel). The coloured arrows indicate that decreasing concentration leads to higher probability in a non-linear way.

As indicated earlier, the required level of certainty to avoid non-linear climate change events with irreversible and probably catastrophic impacts may be much higher, like 95%. While the uncertainty about when such events may happen is still very large, the IPCC TAR and more studies indicate that the risk of such large-scale singularities may increase significantly when global average temperature increases more than 5 ºC above pre-industrial levels. This excludes the finding also reported in the IPCC-TAR that, if the local average temperature on Greenland increases more than 2.7 ºC and is sustained for millennia, a complete melting of the Greenland ice sheet (except for some glaciers in high altitudes) is possible, which would result in an eventual global sea-level rise of up to 7 meters. Note that according to Figure 5.2, the ratio of local-to-global warming on Greenland is about 1-2, so that a local temperature target of 2.7 ºC corresponds to a global target of about 1.4-2.7 ºC. Figure 5.6 indicates that in order to avoid global average temperature to increase by 5 ºC above pre-industrial levels with a probability of 95%, the CO_2-eq. concentration would have to be stabilized below 600 ppmv according to Forest et al (2002). Since there exists a possibility of very high climate sensitivity values according to Andronova and Schlesinger (2001), their PDF estimate implies that CO_2-eq. concentrations need to be stabilized at a lower level of 400 ppmv to attain such a probability of 95%. The difference in PDF shape as shown in Figure 5.4 result in different shapes of the curves in Figure 5.5 and Figure 5.6. The results discussed here illustrate the importance of reducing the uncertainty in the (PDFs of the) CS.

As argued earlier, because of the large inertia in the climate system stabilization of GHG concentrations might not be the most sensible target. Concentration might be allowed to peak and decline afterwards (illustrated in Figure 5.7) to avoid a further increase in climate change that would result from a continued stabilization of concentrations. Indeed, for meeting the same long-term temperature target, concentrations may even be allowed to peak earlier at a higher level than for stabilizing (Figure 5.7).

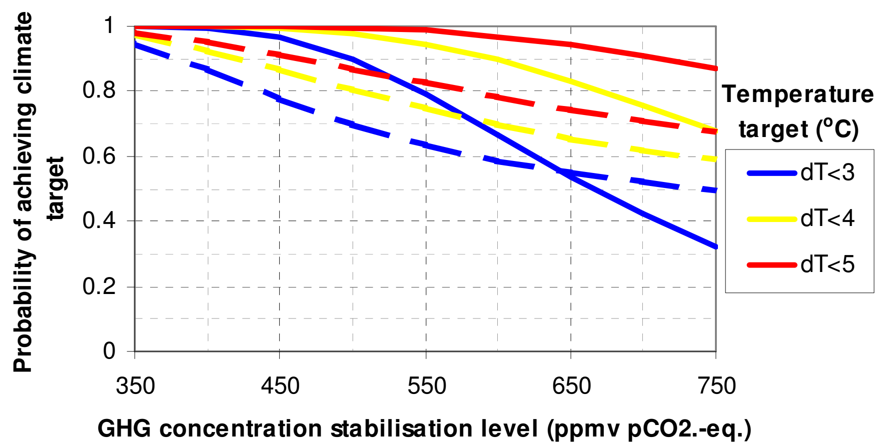

Figure 5.6 Probability of achieving high temperature targets for a range of stabilization targets.

Note: This is implied by the probability distributions for climate sensitivity of Forest et al. (2002) (full lines) and Andronova and Schlesinger (2001) (dotted lines).

As will be discussed below (section 5.4), this may be attractive for reducing the rise of mitigation costs, as these peaking (or overshoot) scenarios will allow for higher near-term emission levels than stabilization scenarios.

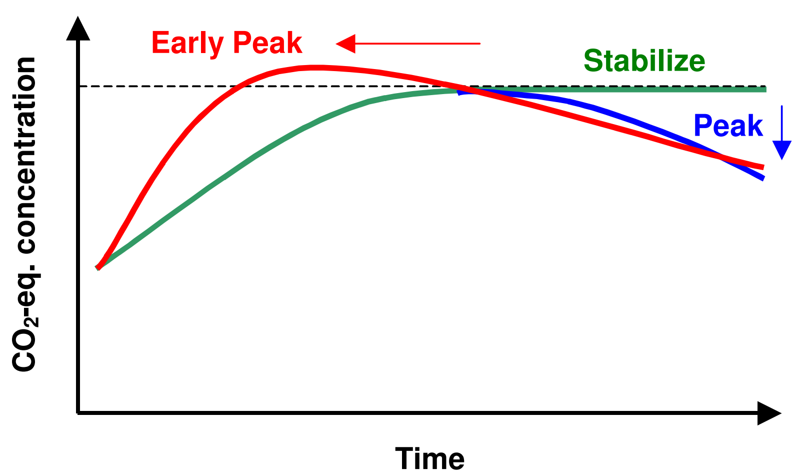

Figure 5.7 Illustration of stabilization and peaking scenarios.

For constructing such peaking profiles and assessing the climatic consequences, the simple calculations used in the above and explained in the Box 5.1 do not suffice. Instead, a climate-modelling tool is required to link concentration levels to climate targets, which adds modelling uncertainty to the assessment. For the analysis below, we have applied the simple climate model MAGICC (Raper & Cubasch, 1996: Wigley, 2003), which in the past decade was also used for illustrating many global-warming issues in

the IPCC reports (Cubasch et al., 2001). The peaking profiles were constructed according to the ‘Peak’ example in Figure 5.7. Emissions continue to decline with a fixed percentage after the concentrations reach the stabilization level, thus gradually reducing concentrations afterwards. This fixed percentage is the same that led concentrations from 1990 levels to the stabilization level. Using the Forest et al. (2002) PDF estimate, for a peaking of CO_2-eq. concentrations at 550 ppmv the probability is about 33% that temperature will stay below a 2ºC target (right panel), which is equal to the value for the stabilization target in Figure 5.5 (left panel). However, in case of a higher climate-sensitivity, for which lower concentrations suffice to achieve a temperature target, the probability of achieving a certain temperature target is higher for the peaking profiles than for the
stabilization profiles. It is a characteristic of the climate system that the time scale of the response is longer in case of higher climate sensitivity. Combining the slow response at high climate sensitivity with the implied high climate sensitivity at low concentrations means that the difference between the stabilization and peaking approach will be larger at lower concentrations (and less stringent temperature targets). Consequently, the results show that the probability of achieving the 2ºC target at a CO_2-eq. concentration of 450 ppmv is almost 90% in the peaking approach (, left panel) versus 75% in the stabilization approach (Figure 5.5, left panel).

An advantage of using a climate model for calculating probabilities is that other indicators can be included, like sea-level rise. Using the same model as above, we have calculated long-term (year 2400) sea-level rise probabilities. It should be noted that the uncertainty in climate sensitivity is only one in a set of factors that give rise to the large uncertainties in future sea-level rise projections (IPCC WG1, 2001). For these other factors we simply assume central values for the concerned parameters in the MAGICC model, instead of a probability distribution approach used for the CS. The certainty of meeting sea level targets might therefore very well be smaller than indicated in . Nevertheless, the calculations already show the probability that long-term sea-level rise will be limited to 50 cm to be less than 10%, respectively 1% for the peaking of CO_2-eq. concentrations at 550 and 650 ppmv. Thus, the probability that this sea-level rise target of the Netherlands is met is much smaller than the chance of achieving the 2ºC temperature target.

5.4 GHG concentrations and emission profiles

The final step in analysing the implications of long-term climate change targets is translating GHG concentration targets into GHG emission pathways.

The concentrations of a particular GHG in the atmosphere is determined by the level of emissions and the removal by chemical processes in the atmosphere and/or absorption by vegetation and water surfaces (oceans).

The rate at which different GHGs are removed is determined by their average atmospheric lifetime: the time needed for halving the initial concentration.

In order to stabilize GHG concentrations the emissions should balance the removal processes, which means in practice that very large reductions of emissions are needed, particularly for those GHGs that have a long to very long atmospheric life time.

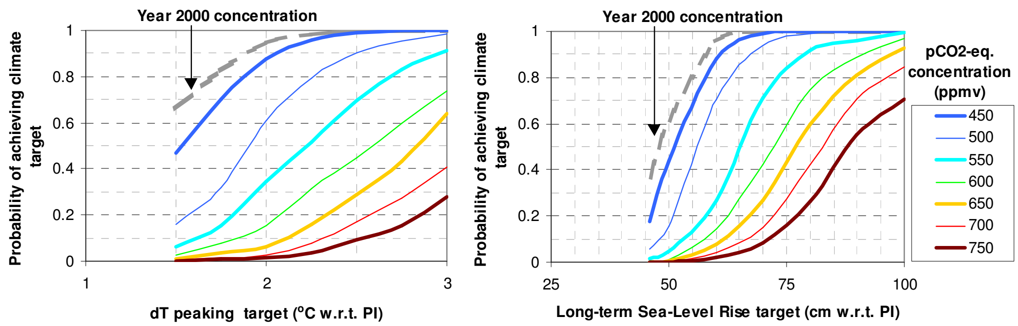

Figure 5.8 Probability of achieving a temperature peaking targets (left panel) and long-term sea-level rise targets (right panel) for a range of CO_2-eq. peaking levels.

Note: This is implied by the probability distributions for climate sensitivity of Forest et al. (2002).

The time span needed for establishing this balance determines the level at which the GHG concentrations are stabilized. Lower stabilization levels thus require earlier and deeper reductions of GHG emissions than higher levels.

In the past, efforts of constructing emission pathways for stabilizing concentrations particularly focused on CO_2 emissions. In 1994, Enting et al. published the first co-ordinated attempt to determine CO_2 emission profiles that lead to several CO_2 stabilization levels (Enting et al., 1994). These CO_2 concentration profiles, published in the first IPCC assessment report (Houghton et al., 1994), were called S350–S750 (which refers to the CO_2 stabilization levels) and had smooth transitions from the 1990 level (± 355 ppmv) to the stabilization level. Later, Wigley et al. (1996) developed an alternative set of CO_2 stabilization profiles that departed less quickly from trends in unabated emissions arguing that this so-called delayed response would be more cost-effective than the S-profiles. These WRE profiles afterwards were used for the Third Assessment Report of IPCC (IPCC, 2001). Only more recently, there have been attempts to include other GHGs than CO_2 only. This shift to a multi-gas approach only started near the end of the 90s, due to the inclusion of 6 major GHGs (CH_4, N_2O, HFCs, PFCs and SF_6) in the Kyoto Protocol and the insight that a 'multi-gas' approach might also be much more cost effective (Reilly, 1999).

Among the first studies defining multi-gas emission pathways for stabilizing GHG concentrations was the Global Reduction Pathway study for the European Commission (Criqui et al., 2003), based on analysis with the IMAGE-2.2 model (Eickhout et al, 2003). The study focused on developing multi-gas emission profiles for stabilizing the CO_2-equivalent concentration at 550 and 650 ppmv (Figure 5.9). In contrast to earlier stabilization profiles the implications of the Kyoto Protocol are taken into account.

Figure 5.9 shows that in order to stabilize GHG concentrations at 550 ppmv CO_2-eq. global anthropogenic emissions (including both energy, industry and land use emissions) will have to peak before 2020 at a level about 35% above 1990 levels.

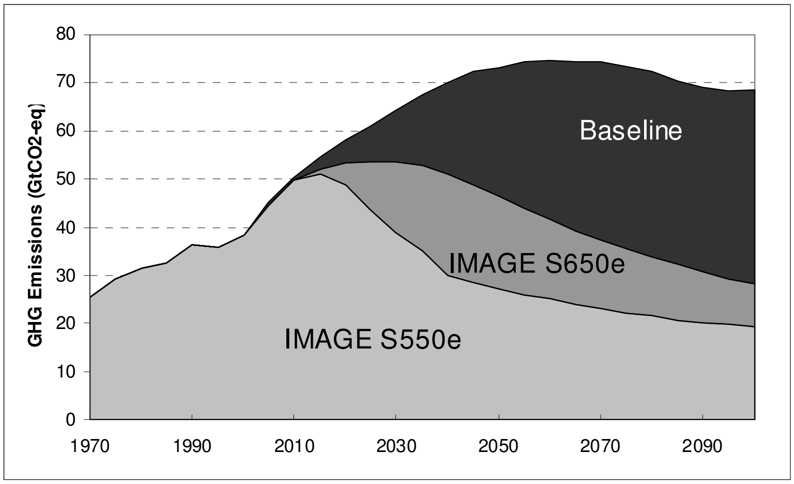

Figure 5.9 Global emission pathways for stabilizing the CO2-eq. concentrations at 550 and 650 ppmv according to the IMAGE-2.2 model (Eickhout et al., 2003).

By the 2030s emissions would need to have returned to 1990 levels. For stabilizing at 650 ppmv CO_2-eq. global emissions could peak later at a higher level and need to return to 1990 levels at a much later stage. In fact, this stabilization level would allow for many different emission pathways for stabilizing GHG concentrations. Low stabilization levels leave
little room for optimisation: e.g. for stabilizing at 550 ppmv CO_2-eq. the global emissions need to peak within 20 years from the present-day, or concentrations will exceed this level. At higher stabilization levels emission profiles can be varied concerning gas mixture and/or over time, including reduction delays compensated by steeper reductions later on.

However, as discussed in the previous sections, if the long-term climate target is defined as a temperature target, like the 2 °C target, the concentrations may peak at a higher level than 550 ppmv CO_2-eq. This would imply a temporary "overshoot" of the concentration level, but the inertia of the climate system prevents temperature to closely track this overshoot. In fact, if a temperature target is selected, there is no compelling reason for focusing on stabilizing GHG concentrations any longer, since part of the residual warming can be avoided by reducing the GHG concentration levels again. The implications of these peaking instead of stabilization pathways are subject of ongoing research, but it is clear that these will provide room for somewhat delaying global emissions to peak for meeting stringent targets and thus make attaining these probably less costly than in the case of stabilization pathways.

5.5 Conclusions

In the back-calculation of concentrations from global-mean temperature targets, the dominant uncertainty is in the value of the climate sensitivity. By use of recent probability estimates of this parameter, risk assessment becomes possible, which is a useful method for evaluating policy options in the context of major uncertainties. For a stabilization at 550 ppmv CO_2-eq. the probability of limiting temperature increase to 2 ºC is about 33 - 50%. For stabilization at 650 ppmv this decreases to less than 10 - 33%.

A 100% probability is unachievable, because of the uncertainty in probability estimates of the climate sensitivity, but also because of other uncertainties in the climate change cause-and-effect chain. An important observation is that the probabilities depend non-linearly on concentration levels. For the 2ºC target the probability of achieving this target increases most rapidly with decreasing concentrations at medium-to-low stabilization levels.

Because of large inertias in the climate system, the full temperature consequences of sustained variations in radiative forcing are not felt for many decades to centuries. Therefore, if concentrations are lowered immediately after stabilization, the full consequence of the peak concentration is moderated. Long-term stabilization of GHG concentrations might therefore not be the most sensible target, especially since temperature change is a more appropriate indicator of climate change impacts.

Current estimates show that in order to stabilize GHG concentrations at 550 ppmv CO_2-eq. global anthropogenic emissions (including both energy, industry and land use emissions) will have to peak before 2020 at a level about 35% above 1990 levels. By the 2030s emissions would need to have returned to 1990 levels. For stabilizing at 650 ppmv CO_2-eq. Global emissions could peak later at a higher level and need to return to 1990 levels at a much later stage. Low stabilization levels leave little room for optimization: e.g. for stabilizing at 550 ppmv CO2-eq. the global emissions need to peak within 20 years from the present-day, or concentrations will exceed this level. At higher stabilization levels, emission profiles can be varied concerning gas mixture and/or over time, including reduction delays compensated by steeper reductions later on.

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6. Macroeconomic impacts of GHG stabilization

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6.1 Introduction

This chapter reviews recent research into the costs of climate change policies that aim at stabilizing GHG concentrations in the atmosphere, preferably at "safe" levels. "Costs" can be evaluated at different levels, for different actors and for different purposes. In order to avoid confusion it is useful to distinguish between three types of costs in the context of climate change and climate change policies:

- Costs of mitigation of net GHG emissions;
- Costs of adaptation to the impacts of climate change; and
- Costs of the (residual) impacts of climate change.

These three types of costs are interdependent. With more mitigation there will be less climate change and hence less need for adaptation and less residual impact costs. Given a level of mitigation, there is a trade-off between adaptation and residual impacts. The *economic* challenge for climate change policies is to find a mix of mitigation, adaptation and residual impacts that will minimize the sum of the three cost components in a way that is also acceptable from a distributive point of view (a fair sharing of the economic burdens). While the above statement is accurate for the global level, it is important to mention upfront that at a national level there is no trade-off between the costs of limitation measures and reduced efforts for adaptation. That depends on the willingness with which other countries participate in the process.

This review only deals with mitigation costs. Although adaptation and direct impact costs are not addressed in this chapter it should be realised mitigation costs will avoid, to some extent, adaptation and direct impact costs in the future. Therefore mitigation costs can be regarded as the "gross" costs of climate change policies; the "net" costs being the mitigation costs *less* reduced costs of adaptation and impact.

The "gross" mitigation costs can be divided into:

- Direct costs of mitigation (the costs of technology and resources), and
- Indirect costs because of the macroeconomic repercussions of the mitigation measures (on relative prices, such as wages, and trade flows) and on other positive or negative side effects of the mitigation measures (for example on the emissions of non-GHG pollutants).

The costs of the same measure (or policy "package") can be evaluated from different perspectives. For the individual household or firm, the costs of a mitigation measure will depend on the change in final energy prices, including taxes, subsidies and other financial and fiscal consequences. For a country (or economy) as a whole, however, taxes and subsidies are no costs, but *transfers* from one economic agent to the other.[21] For a country as a whole, costs are the *foregone* revenues of resources (capital, labour, raw materials and energy) that could have been employed alternatively (opportunity costs). Costs evaluated from the national level are called “social costs”.[22]

Finally, (social) costs should not be equated with financial transactions. Costs can also be of a non-financial nature. Environmental costs, for example, are real costs, but they do not often result in financial transactions.[23]

In sum, this chapter reviews recent research into the direct and indirect social “gross” *mitigation costs* of climate change policies that aim at stabilizing the concentrations of greenhouses gases in the atmosphere at “safe” levels. To put the cost estimates of this chapter in perspective, Section 6.2 briefly discusses the scope and limitations of modelling long-term mitigation costs. Section 6.3 discusses the “perception” of costs: when are costs too high? Section 6.4 presents estimates of mitigation costs, while Section 6.5 examines potential co-benefits of mitigation options. Finally, Section 6.6 concludes.

6.2 Scope of limitations of the modelling of long-term mitigation costs

To put the mitigation cost estimates of this chapter into perspective, this section briefly discusses the methodologies that are used to generate these estimates. The research tools include mathematical models that try to capture some key aspects of reality, but yet are simple enough to be tractable. Given the scope of the assignment – modelling global economic and environmental developments over the course of a century (or more) – there is no way that these models can be validated in any meaningful sense. Modellers in this area never claim to be able to predict the (economic) future; they develop “scenarios”, i.e. more or less complex “what-if” exercises. “*What if*” the global economy would grow by three percent per year in the next century, what would the emissions of GHGs be in the year 2100? Or: “*what if*” climate change policies would increase the rate of technological progress in the production of renewable energies, what would the effect be on mitigation costs?

The models cannot therefore “predict” the costs of climate change policies with any precision; their results are always contingent upon a host of simplifying assumptions that may be adjusted if more knowledge on economy-climate interactions is acquired. At the moment it is assumed that the following assumptions play a major role in the assessment of mitigation costs in the longer term:

The baseline or reference scenario. What would be the developments in the economy, population, technology, and energy resources without climate policies? In general, the higher the economic and emissions growth in the baseline scenario, the higher the effort and therefore the costs of reducing emissions to some predetermined level.

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21 This does not mean that taxes and subsidies cannot lead to real costs at the national level; they can – and this is an important research area for economists.

22 The adjective “social” in social costs refers to the national perspective; not to “fairness” or related associations of the word “social”.

23 And hence, environmental costs are usually not reported in National Income statistics.

The mitigation policy regime. The policy regime in which the mitigation measures are taken can have a large impact on the mitigation costs. Key elements of the policy regime are the extent of country participation, the ability to select the cheapest mitigation options domestically and internationally through Joint Implementation, the Clean Development Mechanism or through emissions trading, the timing of the reduction efforts and the flexibility of the regime in the face of unexpected external shocks. Moreover, the rules for the allocation of the reduction burden across countries and sources can have important consequences for the *distribution* of costs.

The flexibility of the economic and energy systems and the institutional infrastructure. The costs of mitigation measures also depend on the assumptions on the flexibility of the economic and energy systems and the general institutional infrastructure to adjust to the changing economic circumstances because of the climate change policies. In general, the more flexible the underlying systems, the smaller the mitigation costs will be.

The rate and nature of technological progress in mitigation technology. One of the most hotly debated issues of this moment is to what extent technological progress in mitigation technology is encouraged by climate change policies and what the effect of this technological progress on mitigation costs will be. Model applications use two alternative assumptions on technological progress: 1) an *exogenous* rate independent of any policies but based on historical trends, or 2) an *endogenous* rate that depends on the stringency of climate change policies. Proponents of the endogenous representation of technological progress claim that this approach is more realistic and that it leads to lower mitigation costs. However, not all experts agree and this is still an area of intense academic debate.

Co-benefits of mitigation measures. The principal aim of GHG mitigation is to curb climate change. However, mitigation measures may also have co-benefits, for example in the form of reduced emissions of conventional air pollutants such as sulphur dioxide, nitrogen oxides and particulate matter.

6.3 The perception of costs: when are costs "too high"?

Some cost estimates of GHG mitigation in the long-term, published in the Third Assessment Report of IPCC (IPCC WG3, 2001), sparked off a discussion on the relative size of these costs, with some people claiming that these costs would be "too high", and others claiming that these costs would be perfectly affordable. Why is there such a difference in the *perception* of costs?

Figure 6.1 reproduces the cost estimates from the IPCC report. A number of economic models estimated the total *discounted* costs of stabilizing CO_2 concentrations at different levels: from 450 ppmv to 750 ppmv. The *lower* the final level at which GHGs are stabilized in the atmosphere, the *lower* the risks of dangerous impacts, and the *lower* the need for costly adaptation measures (e.g. against sea-level rise). However, the model estimates of show that the mitigation costs *rise* with lower stabilization targets, and they rise more than proportionally.

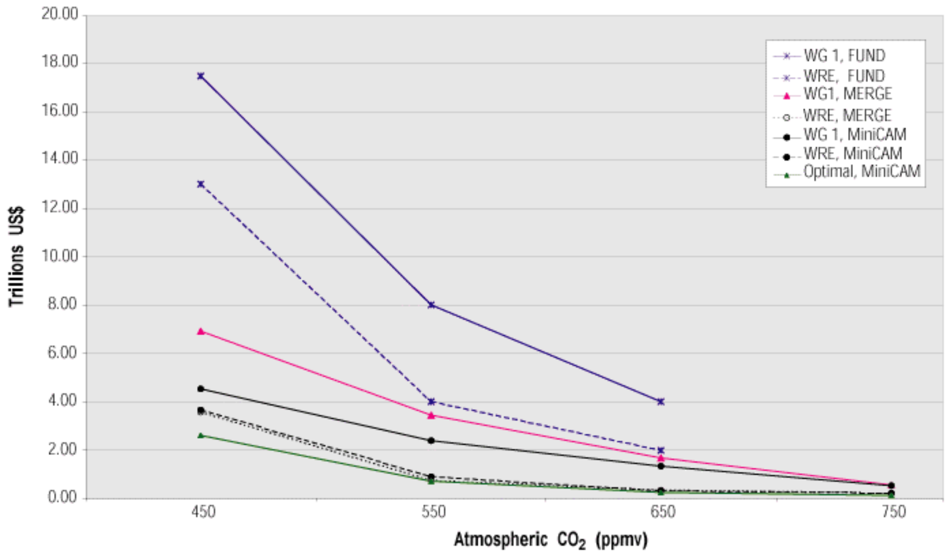

Figure 6.1 Some model estimated of total discounted mitigation costs of stabilizing atmospheric CO_2 concentrations at different levels (450-750 ppmv).

Source: IPCC WG 2 (2001).

Total discounted mitigation costs of the lowest – and presumably "safest" – stabilization target (450 ppmv) have been estimated at US$ 2.5 to 18 trillion (=$18x10^{12}$). Total discounted mitigation costs of higher stabilization targets were estimated at US$ 1 to 8 trillion for 550 ppmv and US$ 0.5 to 4 trillion for a stabilization target of 650 ppmv.

How high are these costs? It depends, of course, what they are compared with. A few examples may help to illustrate this point.

The highest cost estimate in Figure 6.1 is US$ 18 trillion. This is a huge number in comparison to current world income, which is about US$ 20 trillion (Azar & Schneider, 2002). Some economists have, therefore, over the years, warned that costs of this order of magnitude would pose serious risks to the world economy (Nordhaus, 1990; Linden, 1996; Michaels & Balling, 2000).

Azar and Schneider (2002) and others disagree with this view. They argue that the projected income growth over this century, which is the basis of the emissions scenarios on which the cost estimates have been built, is so large that even the largest estimated mitigation costs would do no more harm than delay an impressive [projected] per capita income growth over the next century by a few years. They note: "To be ten times richer in 2100 AD versus 2102 AD would hardly be noticed and would likely be politically acceptable as an insurance policy against the spectre of potential 'dangerous' climate changes by most risk-averse people." (Azar & Schneider, 2002).

The perception of the size of mitigation costs can also differ when the costs are expressed as a percentage of annual (world) income. Typically, mitigation costs of a policy that aims at a "safe" level of stabilization are estimated to be around one to four percent of world income (or Gross World Product: GWP) by around 2050. According to Azar and Schneider's way of reasoning, this is still not much, given the projected growth of per capita incomes. However, if one compares these costs of one to four percent of world income to the share of present and projected energy costs in total income, which is about six to eight percent and falling (2003), then the mitigation costs appear much larger again.

In a reaction to Azar and Schneider (2002), Gerlagh and Papyrakis (2003) argue that the above comparisons make little sense. They argue that even the most extreme estimates of the *benefits* of climate change stabilization policies (i.e., measured as the *avoided* costs of adaptation measures and residual climate impacts, see Section 6.2 above), would also not cause more harm to world income than a few years delay in growth over the next century. They argue further that the real question is to what extent we allow the environment to deteriorate in order to gain extra income. Or in more technical parlance: whether it is correct to assume "that an increased consumption of man-made goods can [indefinitely] substitute – in terms of welfare – for environmental damages due to climate change" (Gerlagh & Papyrakis, 2003:327).

Gerlagh and Papyrakis thus seem to suggest that the degree of mitigation (and the choice of the stabilization target) is *in essence* a political question that goes beyond the realm of conventional economics. Another interpretation is that a limited substitution between climate quality and money income *could be* a characteristic of people's utility functions. This means that people's *willingness to pay* to avoid climate change could be greater than the *expected* avoided costs of adaptation and residual impacts.[24] There could be several reasons for that, including risk-aversion, ethical constraints, or distributional objectives when people believe that climate change impacts will disproportionally hurt poorer people. In this latter interpretation, the limited substitution in people's utility functions (and their true *willingness to pay*) "only" needs to be disclosed by research to bring the question back into the realm of economics.

Given all these considerations, one can argue that mitigation cost estimates cannot be used as thresholds, in the sense of "this cost is clearly too high" or "this cost is just acceptable". Although mitigation cost estimates *alone* are not decisive for the final trade-off between environmental quality and income, nobody will deny that these estimates do provide potentially important information about climate change policies that can and should be factored in into (political) decision making. The next section presents two very recent estimates of long-term global and regional mitigation costs.

6.4 Global and regional costs of meeting possible climate change policy targets

6.4.1 Introduction

Very recently, both The National Institute for Public Health and Environment (RIVM) and the Dutch Central Plan Bureau (CPB) published estimates of the global and regional mitigation costs of meeting possible climate change policy targets. This section presents and compares these estimates.

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[24] *Expected* costs measure the product of the costs of certain events and the probability that they will occur.

6.4.2 The RIVM study

RIVM carried out a study into the technical, economic and environmental implications of climate change regimes that aim for the stabilization of GHG concentrations in the atmosphere at 550 ppmv and 650 ppmv,[25] respectively (van Vuuren et al., 2003a). The 550 ppmv target is likely to limit global temperature increase below 2^o C over pre-industrial levels, while this is unlikely for the 650 ppmv target. While an increase of 2^{o}C is expected to affect the most sensitive ecosystems (coral reefs, polar and mountainous ecosystems) and may increase extreme weather events, the risks of large-scale discontinuities such as the shutdown of the North-Atlantic thermohaline circulation (THC; the Gulf Stream) are low. Also, the *rate* of temperature change is reduced in comparison to the unconstrained baseline, although this rate will still be above “the maximum level [that] ecosystems are historically adapted to” (Rijsberman and Swart, 1990) at least until the year 2090. The environmental risks of the 650 ppmv stabilization target are obviously higher: they are generally in the ‘moderate’ impact category.

RIVM (2003) estimated the direct mitigation costs[26] over this century of (various variants of) international mitigation regimes as a percentage of Gross Domestic Product (GDP) of various world regions. The estimates of these costs are based on bottom-up cost assessments including energy system effects and endogenous technology development (“learning-by-doing”). The most important conclusions are:

- The direct mitigation costs for the 650 ppmv target gradually increase to a maximum of 0.3 percent of GWP (Gross World Product). The direct mitigation costs for the 550 ppmv target rise much faster to about 1 percent of GWP in 2050 and slowly decrease thereafter to about 0.6 percent of GWP;
- There are significant differences in direct mitigation costs between world regions and between various implementation regimes. From a general perspective, four different groups of countries can be distinguished on the basis of their levels of GHG emissions and income per capita. For a mitigation profile with the 550 ppmv target, direct mitigation costs as a percentage of GDP in 2025 are (see Figure 6.2).

1. *0.5 – 1 percent* for countries with high emissions and high incomes (OECD);
2. *1 – 2 percent* for countries with high emissions and low/medium incomes (former Soviet Union, Middle East, Turkey);
3. *0 – 0.3 percent* for countries with low/medium emissions and low/medium incomes (Southeast and East Asia);
4. *0 to negative costs* for countries with low/medium emissions and low/medium incomes (South Asia, Africa).

These direct mitigation cost estimates suggest that the overall economic effects of GHG stabilization policies may be limited, especially considering the fact that the *reference* growth in GDP in the underlying economic scenario is quite substantial (see also Section 6.3 on the “perception of costs).

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[25] Ppmv is a measure of concentration: parts pro million by volume. The pre-industrial concentration of GHG is commonly estimated to have been.

[26] See Section 6.1 for a discussion on different cost categories.

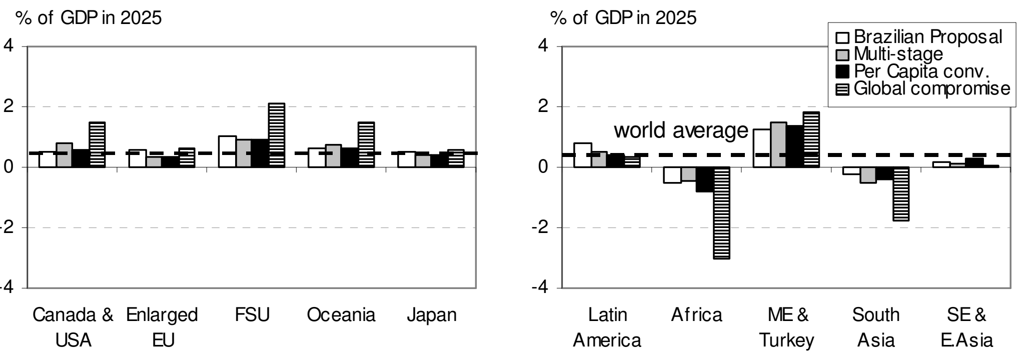

Figure 6.2 Direct mitigation costs in different implementation regimes as percentage of GDP in 2025 for various country groups.

RIVM points out, however, that these direct mitigation costs are only one of the elements that determine the full economic implications of the mitigation policies. Other important elements are the potential co-benefits of mitigation policies in the form of reduced emissions of conventional air pollutants (see Section 6.5) and the indirect macroeconomic implications of the GHG mitigation measures. RIVM notices that, for example for the Middle East, reduced fossil fuel (oil) revenues may be at least as important a cost category as the direct mitigation costs.

6.4.3 The CPB/RIVM study

In a very recent study, CPB/RIVM assessed the full long-term macroeconomic implications of a climate change policy regime that aims at the stabilization of GHG in the atmosphere at a concentration of 550 ppmv (Bollen et al., 2004). To be able to reach that objective, the upward trend in global emissions should be turned down by 2025, and by 2040 global emissions should be almost 20 percent below their 2000 levels.

This reduction of emissions should take place in a global economy that is assumed to grow by 2.5 percent per year (Europe 1.5 percent) and whose use of primary energy would double in the absence of climate change policies (growth of 1.7 percent per year).

CPB/RIVM note that the participation of developing countries in global mitigation would be necessary because of their strong growth of emissions. It is therefore assumed that all world regions would be allocated emissions quota and that the regions would be free to trade emissions allowances amongst each other.[27] Regions with high mitigation costs could therefore buy emissions allowances from regions with low mitigation costs. Hence, the total economic impact would not only depend on direct mitigation costs, but also on the income received or spent on the sales or purchases of emissions permits.

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[27] The initial allocation of emissions allowances across regions is based on an equal per capita emissions level. Specifically, after the first commitment period of the Kyoto Protocol (2012), regional emissions allowances *contract* and *converge* to an equal per capital level in 2050. For Europe this implies that its emissions *allowance* in 2040 would be 80 percent below its actual emissions in 2000. The emissions allowance of Asia and Africa would be twice their emissions in 2000 (but less than their emissions *would have been* without climate change policies).

Moreover, real income would also be affected by so-called terms-of-trade effects, measuring the relative prices of imports with respect to exports. Table 6.1 presents the estimated effects of GHG stabilization policies on the income of world regions, distinguishing between direct effects on GDP and income transfers because of permit trading and terms-of-trade effects.

Table 6.1 Costs of stabilization at 550 ppmv in 2040.*

	GDP	Permit transfers and terms-of-trade	Income
Europe	– 0.9	– 1.3	– 2.2
USA	– 0.6	– 1.3	– 1.9
Former Soviet Union	– 5.6	– 0.8	– 6.4
Middle-east/North Africa	– 6.9	0.1	– 6.8
Asia/Africa	– 2.2	2.4	0.2
World	– 1.6	0.0	– 1.6

* In the STRONG EUROPE scenario. Source: Bollen et al. (2004).

The effects of this GHG stabilization scenario on the global energy market are considerable. Under this scenario, global demand for energy remains at its present (2000) levels, while it *would have* doubled in the absence of the GHG mitigation measures. Especially coal is hard-struck. Its share in the global energy mix decreases from 25 percent in 2000 to 10 percent in 2040. The global share of gas increases from 25 percent in 2000 to 34 percent in 2040, while the share of bio fuels, solar and wind energy more than triples to 22 percent of energy demand in 2040.[28]

CPB/RIVM also assessed the effects on real national income of 1) a climate change policy aiming at a less stringent stabilization target of 650 ppmv, and 2) a reference scenario with higher growth and energy consumption (GLOBAL ECONOMY).[29] The conclusions are that 1) the economic effects of the 650 ppmv stabilization target are near to negligible for the STRONG EUROPE scenario, and relatively small for the GLOBAL ECONOMY scenario, while 2) increased economic growth and energy consumption in the reference scenario (as in the GLOBAL ECONOMY scenario) would strongly increase negative income effects on the global and European economy up to minus 5.2 percent for the world economy and minus 6.7 percent for the European economy.

CPB/RIVM notes that the GHG stabilization scenario results in considerable co-benefits in the form of 50 to 70 percent less emissions of conventional air pollutants such as sulphur and nitrogen emissions. The strongest co-benefits are to be found in developing countries, because of their initial high dependency on coal and lax air pollution control policies.

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28 The role of carbon sequestration is assumed to be limited in this scenario (CPB/RIVM, 2004).

29 In the GLOBAL ECONOMY scenario global economic growth is 3.1 percent per year and energy consumption grows by 2.3 percent per year.

6.5 Co-benefits of meeting possible climate change targets

The costs of stabilizing GHG emissions can in principle be compared to the avoided costs of adaptation costs and residual damage costs of climate change. In practice, this is not easy due to the large uncertainties of the latter effects and the substantial differences in time scales between emissions and (climate) effects. Moreover, as discussed in Section 6.3, it is unclear whether avoided adaptation and damage costs are a good approximation of the people's true *willingness to pay* to avoid climate change because of risk-aversion, and ethical and distributional preferences.

Given these limitations, it is therefore of considerable interest to assess the cost-effectiveness of policy options to reach predetermined targets of climate change. These targets could, for example, be based on the application of the precautionary principle.

For the evaluation of such policy options it is of importance to include their potential side-benefits, in the form of technology development and diffusion, the security of energy supply or the reduction of conventional air pollutants. The above-mentioned IPPC report reviewed many studies on the co-benefits of GHG mitigation measures. Some of these studies reported substantial co-benefits of an order of magnitude similar to the mitigation costs (expressed in US$ per tonne of carbon), while others reported very small co-benefits.

The recent study by RIVM (van Vuuren et al., 2003a) found substantial co-benefits of stringent climate change policies (550 ppmv target) in Asia. The stringent climate change policies would result in a substantial reduction in the use of coal that would lead to a 50 percent reduction in the exceedance of critical loads for air pollution. This could lead to a reduction in the control costs for air pollution (sulphur dioxide) from US$ 17 to 9 billion.

A study by RIVM/IIASA (van Vuuren et al., 2003b) for the European Environment Agency found potentially sizeable co-benefits of climate change policies for the Pan-European region (Western and Eastern Europe, including western states of the former Soviet Union). To illustrate the point that the co-benefits are not only a function of the stringency of climate change policies but also of the way that they are implemented, the co-benefits in terms of reduced air pollution were computed for three implementation strategies of the Kyoto Protocol:

5. DOA: Domestic action only (no emissions trading);
6. TNS: Emissions trading without “hot air”;
7. TWS: Emissions trading with “hot air”.

Table 6.2 shows that the mitigation costs decrease with emissions trading and the utilisation of “hot air”, but so do the co-benefits in terms of reduced air pollution. Hence, for a complete evaluation of mitigation options all costs and benefits (and their distribution) should ideally be taken into account.

6.6 Conclusions

The assessment of the costs of stabilizing GHG concentrations is subject to many uncertainties. Major cost-determining factors are 1) the target level of stabilization (550 ppmv vs. 650 ppmv), 2) the reference growth of the economy and energy use in the

Table 6.2 Mitigation costs and co-benefits of alternative ways to implement the Kyoto Protocol in the Pan-European region.*

Costs of GHG mitigation in W. Europe (bln €$_{95}$)	DAO	TNS	TWS
Domestic measures	12	2	1
Permits	0	5	3
Total	12	7	4

Co-benefits due to a reduction of air pollution (bln €$_{95}$)	DAO	TNS	TWS
Western Europa	-6.6	-2.9	-1.7
Central/Eastern-Europa	0.0	-0.9	-0.6
Russia & Western-FSU	0.0	-0.2	-0.2
Total	-6.6	-4.1	-2.5

* Note that these cost estimates do not refer to long-term stabilization targets; they refer to the medium-term (2008-2012) reduction of GHGs agreed under the Kyoto Protocol.
Source: van Vuuren et al., 2003b.

absence of climate change policies, and 3) the rate of technological innovation and diffusion in the energy system. For the macroeconomic implications of long-term climate change policies, indirect costs (e.g. terms-of-trade effects) are as important as direct mitigation costs. Cost estimates of stabilization target of 550 ppmv for Europe range from direct mitigation costs of 0.5 to 1 percent of GDP to income losses of 2 to 6 percent of GDP in 2040. For the world these estimates range from 1 percent, respectively 1 to 5 percent of GWP in 2040.

Both the RIVM and the CPB/RIVM studies note the potential of co-benefits of GHG stabilization policies in the form of a reduction of conventional air pollutants. CPB/RIVM estimated that a GHG stabilization scenario results could result in a reduction of 50 to 70 percent of the emissions of conventional air pollutants such as sulphur and nitrogen. The strongest co-benefits are to be found in developing countries, because of their initial high dependency on coal and lax air pollution control policies.

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7. Stakeholder evaluation

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7.1 Introduction

Let us return to the problem defined in Chapter 1. The question of what is dangerous is dependent on societal perceptions as well as scientific information. In order to further understand the kinds of visions that exist in society, the following steps were undertaken:

- 30 interviews with stakeholders were conducted (see 7.2);
- A first workshop, with 22 stakeholders and 13 members of the research team participating, was organised (see 7.3); and was followed by;
- A second smaller workshop with 10 stakeholders and 10 team members (see 7.4).

This chapter systematically goes through the results of each of the phases. Before going further, it might be useful to mention that this is not a survey of public opinion in the country. This project is based on trying to access the key social actors and stakeholders who have thought about climate change and its potential impacts, in order to understand what their key arguments are and how they perceive the climate change problem. In identifying the stakeholders, the project team made an initial selection of potential stakeholders from the different sectors and backgrounds. Of these, 60 people were short-listed and invited to participate in the process, in the hope that we would be able to secure commitment from 1/4th to 1/3rd of those invited.

In addition to discussing the interview and workshop results, this chapter provides a brief overview of long-term target processes in other countries (see 7.5), before drawing its conclusions (see 7.6).

7.2 Interviews: Initial guidance in articulating Article 2

In order to achieve consistency with other projects on this issue, and to get an initial idea of the different stakeholder perceptions on Article 2, a round of interviews was conducted, with a specific set of questions (see Appendix II). An assessment of the interviews leads to eight inferences.

- First, the majority of the interviewed felt that the most serious problems for the Netherlands were floods, sea-level rise and other issues that affect the water management system in the Netherlands. Other perceived dangers in the Netherlands were: extreme weather events; the spread of disease and health risks; lowering of the water level; loss of biodiversity; the migration problem; and the lack of social awareness in society;
- Second, most interviewees felt that the problem with Article 2 was that it was both clear and unclear. It had clear criteria but was unclear because it did not include security issues, irreversible events, natural climate change and the rate of climate change. The fact that Article 2 was the result of a political compromise and hence open to a number of interpretations made it weaker;

- Third, with regard to the criteria mentioned in Article 2, 38% of the interviewees felt that the ecological risks should be the most important for interpreting Article 2, 34% argued in favour of ensuring that food production is not endangered and 28% argued in favour of prioritising sustainable economic growth;
- Fourth, in determining which climate change risks were completely unacceptable, stakeholders had diverse opinions ranging from irreversible outcomes; loss of inhabitable land in some parts of the world; loss of growth opportunities in developing countries; and high net mitigation costs;
- Fifth, in analysing which policy outcomes were unacceptable, the stakeholders concluded that the non-participation of Russia and the United States in the Kyoto regime was unacceptable. Furthermore, policy steps that did not prevent irreversible outcomes were unacceptable. Other unacceptable outcomes included those that did not lead to policy decisions, or execution of policy decisions, inequitable distribution of burdens and policies that limited the growth opportunities in developing countries;
- Sixth, in terms of who should pay for reducing emissions, the bulk of the interviewees focused on a range of ideas which included the polluter pays principle, the ability to pay principle and the need also to focus on technological developments;
- Seventh, in terms of major anticipated controversies underlying Article 2, there was consensus that this would be on the division of responsibilities between countries, the definition of dangerous, the interpretation of the criteria of Article 2 and the tensions between them, and the role of scientific uncertainties;
- Finally, the importance of Article 2 was also linked to global security issues, trade issues and North-South power relations.

It should be stated that there was a slight bias in the interviews towards more ‘green’ answers, because of the number of stakeholders interviewed from each group. Most responses came from NGOs, whereas the government representatives were the least responsive.

7.3 The first workshop: Identifying indicators

7.3.1 Introduction

These interviews were followed by a stakeholder workshop. There were 21 stakeholders present, a chair from the Netherlands’ Senate (Eimert van Middelkoop), and the project team consisting of 13 researchers.

Table 7.1 Numbers of participants in the first workshop.

	Government & politicians	Industry	NGO	Scientist	Project team
Chair	1				
Stakeholders	4	4	6	7	
Project team					13

The participation at the first workshop indicates a bias towards scientists and NGOs. In the second workshop, the bias was corrected towards more industry and government representatives. This bias is the result of the self-selection of stakeholders. Those interested in the climate change issue are willing to make time to discuss it; those not interested are also less interested to spend time to oppose such a discussion. Such biases are inherent to the stakeholder process and the researchers need to be constantly aware of this.

The purpose of the workshop was:

- To provide all participants with current scientific insights on climate change and its impacts;
- To provide participants with a background on the perceptions of the interviewees on Article 2;
- To introduce them to the methodology of the workshop; and
- To secure a list of possible indicators of climate change.

7.3.2 Climate believers versus sceptics

The workshop began with a debate between a prominent climate change sceptic (Hans Labohm) and the Netherlands Royal Meteorological Institute (Koos Verbeek; see Chapter 2). The underlying intention was to let the stakeholders decide for themselves whether they consider climate change a serious problem or not. Sceptics of climate change form an important segment of stakeholders in society, and it is important to listen closely to their arguments. The key arguments of Mr. Labohm and the responses of Koos Verbeek are summed up in Table 7.2 (Gupta et al., 2004).

Table 7.2 Key elements of the debate between sceptics and believers.

Issue	Hans Labohm	Koos Verbeek
Consensus	IPCC reports are consensus reports; consensus is not science	IPCC scientists are reputed scientists, the reports are subject to extensive review; they provide an assessment of the best available science; consensus is not about the science as such, but about the assessment of the scientific literature
	The summary for policymakers is politically scrutinised before being approved	IPCC authors have a veto right on the policymakers summary and will not approve the text unless the language is acceptable
Uncertainty	The frequent use of the word uncertain in scientific reports shows how unreliable the science is	Uncertainty is a very respectable word in the scientific world; does not show the dubious nature of science, but its complexity
Empirical evidence	The difference between surface temperature as measured and measurements via the use of satellites; the latter shows that there is nothing to be alarmed about	Satellites measure the average temperature in the area 0-8 km above the ground; and cannot be compared to ground temperature

Issue	Hans Labohm	Koos Verbeek
Exclusion of some science	Exclusion of urban heat island effect	The measurements are corrected for the urban heat island effect
	e.g. McIntyre and Mc McKitrick	Is being studied, but is an exceptional report and no other scientists support its conclusion (see also Chapter 2)
	Astrophysics and geologists; For example geologists show that CO_2 increases following a temperature rise and not the other way around	They will be included in the next round of IPCC; there are different processes at work; one relationship does not exclude the other. It has been shown without doubt that increase in CO_2 leads to an increase in temperature, but that does not mean that in some circumstances there may be a reverse relationship
	The role of water vapour	Water vapour is a natural GHG gas; when the temperature increases the concentration of water vapour will also increase
IPCC scenarios	Are based on unrealistic expectations of growth in the South	*Yes, no 'barbarian scenarios' were taken into account based on a collapse of the economic growth in the South; if that happens, the emissions will also fall.*
Cost-benefit	Kyoto implementation is very expensive and the results (a reduction of 0.02) cannot even be measured on a thermometer and is hardly a first effective step towards the long-term goal.	Yes, but Kyoto is only the first step; if Kyoto sends a strong message to society that we need to find alternative approaches, this will lead to technological development and the costs of emission reduction may as a result decrease.
Risk	Is a fact, and not something to be determined by a handful of stakeholders	Risk is a matter of perception and individuals make risk based decisions everyday; stakeholders help to determine the kinds of arguments that exist in a society in relation to how risk should be framed.

Please note: Text in italics show the responses of other participants.

7.3.3 Identifying indicators

Following this debate, the participants were informed about the different impacts of climate change, the economic aspects as well as the role of indicators (see Chapters 3-6). Fact sheets were provided to the participants that covered climate change in general, the Third Assessment IPCC Report, climate change targets and GHG emissions, biodiversity and ecosystems, fresh water, coastal areas, health, recreation and tourism, and macro-economic effects (see Appendix I).

This was followed by the formation of three break-out groups with a comparable heterogeneous composition. However, one group had an industrialist as Chair, another a government official and the third an NGO representative. The idea was that possibly the chairs of the groups would have their own bias in dealing with the issue and that it would be important to see such a bias emerge. Each group was supported by members of the research team.

The group chaired by the government official first discussed the concept of indicators and its usefulness for such an exercise. An indicator presupposes a clear cause and effect; climate change does not yield information that can be used as such; the question is then what is the role of indicators? Is it to discover undesirable effects in time? The link to climate change can be subsequently researched. Indicators could lead to a number of different strategies and one can then compare the strategies in terms of costs. The most important role of an indicator is in communicating complicated information with society. The information in the break-out group has been structured and presented in Table 7.3 in normal text. It differs slightly from the dynamics of the group but is comprehensive in covering the issues discussed. The group short-listed ten categories of indicators and commented on what they thought would be unacceptable thresholds. The focus was primarily on the impacts in the Netherlands, although on some issues they also discussed the international consequences. The second break-out group was chaired by a person from the NGO world. The second group identified ten indicators as critical shown in Table 7.3 in italics. The third group was led by industry. This group spent more time discussing the point of the exercise and then identified six possible indicators shown in bold in Table 7.3. The group felt the need to focus on indicators for Netherlands and Europe.

Table 7.3 thus integrates the results of the three working groups. It shows that 18 indicators were short-listed by the group. It also shows that there was considerable overlap between how the groups thought. But some of the comments also reveal that the participants were not fully able to internalise the information provided to them. The discussions revealed some normativism (e.g. people should have access to water), practicality (e.g. it should be easy to communicate to stakeholders) and attributability (e.g, can the impact be attributed to climate change?).

Table 7.3 Indicators and possible thresholds in the break-out groups.

Indicator	Unacceptable threshold	Focus of the discussion
Liveability	When it is threatened; such as when rising waters affect property	Both national and international
Sea-level rise/ floods	So high and so fast that the physical risks are unacceptable to society	NL can probably cope with some sea-level rise by raising barriers'; Easy to communicate to society
Rivers	Navigability – minimum and maximum levels	National
Climate	Change in precipitation, amount, extremes and variations	National
Water quality	Rise in blue algae and botulism	National
Water security		People should have access to water

Indicator	Unacceptable threshold	Focus of the discussion
Irreversible events in climate system	If the Gulf Stream current turns cold; etc.	Not enough research here; a reasonable expectation of an irreversible event should be enough to lead to precautionary action Important, but difficult to communicate
Food production	If insufficient amounts at low quality can only be produced If global food production or distribution is affected	Global; Can hunger be attributed to climate change or other causes? Reduction of agricultural output as a result of less water can influence social change.
Security	Breakdown in the feeling of security; Regional instability; Risk to sustainable development in regions; Will be affected by changing food production zones (e.g. in the Sahel); loss of income from decreasing fisheries; changes in social instability	Both national and international
Biodiversity/ Ecosystem	High rate of loss of biodiversity Not more than 0.1 degree C per decade; Critical changes	Both national and international; However, can biodiversity loss be attributed to climate change?
Vulnerable groups	Unacceptable risks to vulnerable groups	National;
North-South and population groups	Extreme differences; increases in North-South gaps	Changes in North-South relations and gaps is difficult to measure so that is not a good indicator
Temperature rise		Too abstract for social actors
Economic system	Irreversible changes in the economic system; if the primary sectors (e.g. agriculture) of an economy are affected by climate change, then there will be major economic destabilization.	
Employment	Loss of jobs	
Costs-Benefits		A proactive approach irrespective of the costs is necessary
Health		Was not named as indicator and that was probably, speculated the group, because it is not seen as so important.
Adaptation		A vulnerability indicator is important to understand if people can cope with adaptation.

Note: Text in normal indicates results of group 1, italics, result of group 2 and bold results of group 3.

7.3.4 Identifying criteria for evaluating indicators

In the plenary session that followed, participants felt the need to classify the criteria. They identified four key scientific criteria (representativeness for a larger set of impacts, attributability to climate change, measurability, and reliability) and three social criteria (direct relevance to the Netherlands, understandable and appealing) for evaluating the quality of an indicator.

7.3.5 Driving factors for the Netherlands

In the plenary discussions, several issues came up for discussion, including the need to have indicators that are newsworthy (e.g. malaria in the Netherlands), the role of the fossil fuel industry, and indicators that show whether action can have other benefits. It was also considered very important to focus on avoided costs or benefits of taking action. But every industry and administrator will have to take the costs of measures seriously into account.

In general, the stakeholders had the feeling that the Netherlands is possibly able to cope with a vast range of effects, so that the effects on the Netherlands per se can never be a driving force for action. Having said that, there were three important points to note:

- The loss of biodiversity is not taken into account;
- The Netherlands cannot be seen as an isolated actor in the international society, and it needs to take into account effects that occur also primarily outside the Netherlands; and
- The costs for adaptation for the low-lying Netherlands would not be negligible.

These three reasons were seen as key reasons for taking action. It was also seen as important to ensure that the US and Russia came back into the system. It was argued that one of the ways to do that was if the key large developing countries argued that climate change could potentially destabilize their economies and political systems. It was further pointed out that it was vital that development and climate change policy was integrated from the perspective of the developing countries.

7.3.6 Information needs

In order to be in a better position to discuss impacts and indicators, the participants asked for further information on:

- Information about how to communicate to the public on climate change;
- More specific information on the costs and benefits of climate policy at the national, EU and global levels;
- Further information about how specific ecosystems will be harmed;
- Information to develop the indicators further;
- Information on how to develop the issue linkages with local pollution better.

In particular, it was suggested that the researchers needed to concentrate further on a few points:

- How can the indicators be better classified?
- Under what conditions can we expect abrupt changes and economic destabilization?

- What are the effects with low probability but high impacts?
- How do uncertainties change?
- When do climate variability and extreme events become dangerous to societies?
- What are the costs of the impacts for the Netherlands and for other countries?
- Is it true that the Netherlands can actually cope with a rising sea level and that the citizens will not protest?
- How do we combine absolute changes and the speed with which changes take place?
- What role can business actors play, what do they already do and why?
- How can one anticipate climate changes?
- How can different impacts be combined?

Following the workshop, the project team tried to find answers to the above questions from existing literature, but did not undertake new research.

7.4 The second workshop

7.4.1 Introduction

The second workshop was again chaired by Eimert van Middelkoop. The participation at the second workshop was more limited than the first and the aim was to correct for some of the imbalances in the first workshop (See Table 7.4).

Table 7.4 Participation at the second workshop.

	Government & politicians	Industry	NGO	Scientist	Project team
Chair	1				
Stakeholders	2	4	3	1	
Project team					10

The purpose of the second workshop was:

- To provide feedback to the questions raised at the first workshop;
- To see if there was an effective way to classify the indicators identified at the first workshop;
- To come to an identification of threshold values for the important indicators, and
- To see if there was any way to provide an intelligent response to the current climate change targets of the Netherlands.

The meeting began with a presentation by Eimert van Middelkoop. He made a presentation of the current political context in the area of climate change, which is characterised by:

- An expectation that Russia will ratify the Kyoto Protocol soon[30], making it relevant and urgent for the European Union to start preparing for follow-up measures;
- The political target of the EU is that temperatures should not be allowed to rise beyond 2 ºC; this target will be revisited in the spring of 2005;

[30] See also Environment Daily, 24 May 2004.

- The political target of the Netherlands is that temperatures should not be allowed to rise beyond 2 ºC, which is approximately 550 ppmv CO_2 equivalent;
- The Netherlands' government had just informed the Parliament of its intention to investigate the possibility of reducing emissions by 30% in the developed countries by 2020 in relation to 1990 levels as a first step towards achieving the long-term objectives.

7.4.2 Classifying indicators according to criteria

At the first workshop, participants had identified four key scientific criteria (representativeness for a larger set of impacts, attributability to climate change, measurability, and reliability) and three social criteria (direct relevance to the Netherlands, understandable and appealing) for evaluating the quality of an indicator (see 7.3.4). After several preparatory iterations, based on discussions with scientists and stakeholders, the project team finally prepared an ideal-typical (yes-no) classification of the indicators into four categories. This two-by-two matrix attempts to classify the indicators in terms of their scientific robustness and their social acceptability. The purpose of this table was to provoke discussion and to stimulate the process of understanding how to best further the research on indicators. It should be noted that in the preparatory stages of the workshop, the project team added a few indicators to those selected by the stakeholders in the first workshop, on the basis of their own scientific assessment. The classification is shown in Figure 7.1.

Two break-out groups were formed, again with a comparable heterogeneous composition. The two break-out groups discussed the classification and its purpose. Key concerns were articulated as follows:

- There should be a clearer differentiation between national and international aspects; after much discussion, the group agreed that there should be first a national discussion and this should then be followed by an international discussion;
- All indicators should be classified in a way that they appeal to different stakeholders, since stakeholders have different perceptions, and in a way that is related to their impacts. The classification suggested included: health, ecology, security and the economy;
- Others felt that some indicators represented irreversible events, others reversible;
- Some argued that the time-frames of the impacts (long-term, short-term and continuous) were not adequately taken into account;
- There were concerns about how economic indicators should be dealt with: were they inherently a part of the other impacts, or were they to be generalised into macro-economic indicators; and
- Caution should be exercised in the identification and classification of indicators;
- At a more detailed level, there were questions about whether absolute and relative sea-level rise were classified correctly, whether the reversal of the Gulf Stream was classified correctly, etc.;
- There was some discussion about whether some indicators were too all encompassing (water quality), and some were too specific;
- There was some concern that some indicators were at different points of the chain of effects;

- Some felt that a focus on a "yes-yes" category was useful as a way of prioritising some of the indicators; others felt that many important issues (North-South; security; macro-economic effects) might be lost in the "no-no" category;
- Some felt an important reason for selecting an indicator was whether the impact could be easily addressed;
- Some felt it was important to distinguish between primary and secondary impacts;
- Some felt that an ideal typical approach did not adequately capture the level of nuance in the indicators and that a more scientific approach would be more appropriate; while others felt that the purpose was clear and that maybe some more work needed to be undertaken to make the classification more comprehensible and transparent.

Social Criteria	Scientific criteria: Yes – Scores high	Scientific criteria: No- scores low

Yes – Scores high	Health:
	- Water quality
	  - Water temperature
	  - Access to drinking water
	- Spread of infectious disease
	- Death by heat waves
	- Lengthening of the pollen season
	Ecosystems:
	- Change in the flowering time of plants/trees
	- Disappearance of species
	Security:
	- Melting of glaciers
	- Absolute Sea-level rise
	- Rate of Sea leve lrise
	- Floods
	Economic:
	- Navigability of rivers
		Health:
		- Access to food
		- Global access to drinking water
		Ecosystems:
		- Change in biodiversity
		Security:
		- Disintegration of the West Antarctic Ice sheet
		- Prevention of disasters
		- Number of storms
		- Feeling of security
		Economic:
		- Effects on work
		- Effects on vulnerable sec-tors
		- Effects on the growth of global or national income

No- scores low	Economic: - Productivity of land - Rate at which the beaches disappear	Security: - Impacts on the Gulf Stream - Instability because of North-South problems Economic: - Macroeconomic effects

Figure 7.1 An ideal typical classification of indicators.

7.4.3 Identifying threshold levels

In the second set of break-out groups, the participants were asked to reflect on threshold levels for the different indicators. In focusing on the Netherlands, the groups collectively came to an assessment of 21 indicators and discussed what could be seen as acceptable and not acceptable risks to society. The results of this discussion is shown in Table 7.5. What becomes apparent from the table is that the task was much more labour intensive than the time allotted for the exercise. The stakeholders took some time to warm up to the exercise and were then able to come up with ideas in relation to the first set of indicators, but were unable to complete the list. They, however, did generate a number of arguments about how such threshold levels can be identified. (a) Acceptable risks included incidental impacts, and in the case of sea-level rise a rise of 20 cm per year. (b) Unacceptable risks included structural impacts; impacts that affect the basic comforts of life that people are already used to; negative impacts on electricity production; on the Wadden Sea, where legal norms are exceeded, where it leads to zero growth in national income even if only for a period of one year. At the international level, there was a feeling that there should be no increase in world hunger, lack of access to water and more global inequity.

There were also some discussion points:

- In determining what is a threshold level, should one take into account what is likely to happen, or should one begin from what is desirable? The conclusion was that in such an analysis one should begin from what is desirable, although in some situations one was also implicitly taking into account what was feasible;
- The focus, in the first place, should be on impacts in the Netherlands, but that does not mean that the international consequences are seen as irrelevant;
- Risk is equal to chance multiplied by effect; hence, if the effect is not acceptable, we should not talk in terms of acceptable risk.

In the third and last session of the day, a presentation was made on linking indicators back to emission scenarios (see Chapter 5). Following that, there was discussion in relation to four questions. This is summed up in the next section.

7.4.4 Discussing long-term targets

In response to the question on whether it is useful to have a long-term target in the first place, the feelings expressed were:

- In theory, a long-term target is useful because it ensures that countries are on the right path especially since the responses in the system are slow and long-term, it helps to match long-term scientific with short-term political scales, and provides the justification for short-term action. Some stakeholders raised doubts as to whether the long-term targets really affect the negotiations, which sometimes end up in horse-trading;
- In practice the long-term target does not necessarily pose a problem for industry stakeholders, since their activities are mostly in line with current short-term targets. However, this does not automatically imply that the long-term targets will be acceptable. For the insurance industry, there is no real problem, because if the impacts increase they will increase the premiums; in other words they can adjust fairly easily. At least that was the perception shared at the workshop. The willingness of society to pay the increased premiums was not discussed.

Table 7.5 Indicators and risk levels.

Type	Indicator	Acceptable risk	Not acceptable risk
Water	Quality (the number of weeks one cannot swim)	An increase of 50% from current levels; on a local basis and only incidentally	An increase of 200%; Structural effect annually;
	Access to clean water	That there is a temporary ban on washing cars; or watering gardens	That children cannot take baths; or you cannot drink water from the tap; That international targets are at risk
Limitation of industrial activity (navigability and water temp.)	Navigability of rivers (in weeks)	Incidentally	More than a month/Two weeks
	Water temperature	An incidental rise leading to fish kills	Structural rise leading to loss of biodiversity; Code red: Electricity is rationed, because of the impact on electricity production
Sea-level rise	Absolute (m)		0.5 (1 metre and above is seen as too expensive)
	Rate (mm per year)	20 cm per century	> 50 cm per century; > 3 mm per year, because of the devastating effects on the Wadden sea
Food	Distribution		No increase in world hunger
	Productivity of land		Structural loss to agricultural land
Health	Spread of infectious disease (e.g. Lyme disease)	Doubling of the chance of sickness	If adaptation is no longer possible; or adaptation is greater than the costs
	Death from heat waves	Mortality should remain stable	No increase in mortality
	Increase in the length of the pollen season		Structural increase in chronic sicknesses
Irreversible events	Melting of glaciers		
	Melting of the Antarctic	0%	>0%

	Impact on the Gulf Stream	<0%	>0%
	Disappearance of species		Where the legal norms are exceeded
Tourism	Rate at which the beach disappears		When it affects tourism
	The number of major skating events (*Elfstedentochten*)		< 1 every ten years
Economic	Effect on income		No growth as result of impacts for one year; If Netherlands competitiveness is affected
	Effect on work and sectors		Income inequality in NL must not increase
Security			
Ecosystems			

Note: Text in italics is the contribution of Working Group 2; and normal text is the contribution of Working Group 1. Source: Dalenoord et al. (2004).

The critical issue of the Ministry of Economic Affairs appears to be the effect on the Netherlands' ability to compete on the international market, especially in the context of US non-participation in the regime.

In response to the question of whether the focus of a long-term target should be on concentrations, temperatures or something else, the arguments were as follows:

- A focus on global mean temperature is useful in that it is logical from a scientific perspective, closer to the impacts, representative of a number of impacts, easy to verify, and understandable; even if it is not entirely appealing and too abstract for society;
- A focus on concentrations is useful because it relates quicker to emission levels, even though it is more abstract for society and somewhat further away from impacts.

In response to the question, what is our opinion on the 2 degree Celsius target of the Netherlands' government, the responses were:

From a scientific perspective,

- Beyond 2 °C global warming in relation to pre-industrial levels, there is consensus that the climatic system could become unstable and irreversible impacts may become inevitable;
- It should be noted that 2 °C, still implies huge losses to some low-lying countries and some ecosystems;
- The 2 °C target may have already been exceeded if the sensitivity of the climate system to emissions is higher than currently expected; in other words if the current emissions of aerosols is masking the enhanced greenhouse effect to some extent; However, the IPCC has not yet made any firm assessment of the situation as yet;
- Taking all the above into account, it was agreed that on the basis of the current science, a 2 °C target in combination with current expectations that this coincides

with a 500-550 ppmv CO_2-eq. concentration level seems to be the most reasonable long-term target for the Netherlands.

From a political perspective, there were some discussions:

- Modifying a 2 °C target to a 3 °C target would reduce the urgency for action and increase the risk of instability in the system; this risk was not seen as politically acceptable. Besides, beyond 3 °C the biosphere could become a source rather than a sink of GHGs;
- Reducing a 2 °C target to something lower does not seem at all feasible, especially because of the short-term implications.[31];
- Should the science indicate that the climate system is more sensitive to emissions this would only imply that the urgency to take measures will increase drastically. This is an additional argument for not relaxing the 2 °C target;
- The perspectives of other large EU member states on the issue strengthens the political argument that the 2 °C target is a proper one, since the Netherlands is not alone in this perspective.

7.5 Targets in other countries

Parallel research undertaken by a student involved in the project focused on how other EU countries were looking at the issue of long-term targets. The initial research results show that some countries have targets while others are willing to accept the EU's judgement (see Table 7.6).

The table indicates that the larger and prominent EU member states (UK, Germany and France) and some smaller countries (Sweden) support far reaching long-term targets. Other EU member states, including the new member states, are not undertaking any independent research on to the subject but seem to be (willing to) accept the position of the EU.

The following figure shows the current commitment to long-term targets and timetables.

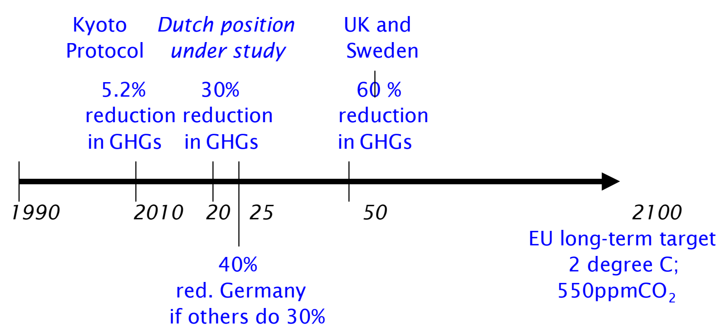

Figure 7.2 The current commitment to long-term targets and time-tables.

[31] Even a 2 °C target appears less feasible in the Dutch context, according to a selection of Dutch stakeholders (see Hisschemöller & van de Kerkhof, 2004, on the feasibility of a –30% target in 2020).

Table 7.6 Perceptions of other EU countries on targets.

Countries	Current perspective on long-term target	Internal process of articulating the target	Comment
Proactive			
Austria	Supports EC position; but thinks it may be too weak	Within the government, discussions on whether limit values on emissions of concentrations should be developed	No real stakeholder process
Denmark	No official position; beyond support of the EC position	No process in place currently	Although the original position was based on stakeholder dialogue, the current government is sceptical
Belgium	No formal position; accepts current EC position	Presently seeking advice on a long-term target from the Federal Council for Sustainable Development.	Stakeholder involvement important. The Federal Council for Sustainable Development, a stakeholder body provides advice
France	Stabilization levels should not rise above 450 ppmv CO_2;	French position outlined by President Chirac and in speech by French minister to IPCC plenary in Jan. 2003	Implication is global emissions must halve by 2050; Annex I emissions must decrease by 50% in this period.
Germany	Supports EC position ; examining potential of stabilizing concentrations at 450 ppmv CO_2.	Germany willing to reduce emissions by 40% in 2025 if the rest of Europe reduces by 30%.	No stakeholder discussion; recognizes original EC position as scientifically incorrect.
Netherlands	Supports EC position;	Exploring a –30% reduction in 2020/ 1990	Stakeholder discussions in process
Sweden	Goes beyond EC position; supports a –60% reduction of CO_2 in 2050/1990		
UK	Supports EC position; -60% target of CO_2 in 2020/1990	Based on internal discussions of science	No stakeholder involvement in discussions. Far greater reliance on science than on the need for social support
Reactive			
Czech	No formal position; accepts current EU position	No formal internal process	No real role for stakeholders
Estonia	No formal position;	No formal internal process	No real role for stakeholders
Finland	Supports EC position	No real internal process	Includes consultation with stakeholders
Italy		No internal discussions	
Malta	No official position	No internal discussions	Sees sea-level rise and water as key indicator

Poland	No official position	No internal discussions
Portugal	No official position; supports EC conclusions;	
Spain	No official position; new government	No internal discussions
European Level		
European Commission	8% reduction in 2008-2012; 1% reduction annually till 2020;	No real discussion on Art. 2
European Parliament	Stabilizing at 550 ppmv CO_2-eq.;	
European Council	Less than 2 ºC; 550 ppmv CO_2	

Source: Compilation from Laschet (2004) and Ott et al. (2004).

7.6 Conclusions

The interviews and workshops lead us to the following conclusions. There are enough reasons for key actors in the Netherlands society to pursue an articulation of the global long-term targets. A combination of political and scientific reasons led participants to conclude that the 2 °C target should form the long-term goal of the Convention, and that a –30% reduction in 2020 for the EU countries possibly is an inevitable short-term target that is consistent with that goal. The long-term target did not pose any major problems to industry. While for some industry (e.g. insurance) the short-term target did not pose any key problems, others had some reservations about participating if other major actors in the world did not also do so. On the other hand, arguing on the basis of what is seen as necessary to avoid major damages and also what is in line with the current proposals of large EU member states, the –30% target seems reasonable. A recent research document also concluded that –30% reduction is both technologically feasible and affordable if undertaken in combination with emission trading (Bollen et al., 2004). However, another report that evaluated the short-term target through a stakeholder process of –30% argued, *inter alia*, that a –30% target was not as feasible as previously suggested and advised the Netherlands' government not to go into the negotiations with such a target (Hisschemöller and van de Kerkhof, 2004: 3-4). On the other hand, from the perspective of what is seen as necessary, this project argues that if we wish to keep to a 2 ºC target, a –30% target must be seen as a short-term goal.

The workshops also identified criteria for the evaluation of indicators; they identified key indicators and provided a set of reasoning about when indicators may be useful and when not.

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8. Participatory Integrated Assessment

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8.1 Introduction

This chapter integrates the information provided in the earlier chapters in order to assess:

- The indicators for impacts of climate change;
- The threshold levels of what is seen as dangerous from a Netherlands' perspective in relation to the indicators; and hence;
- Key arguments in support of a long-term target on climate change.

This chapter also takes a less nuanced and more ideal-typical approach to collating the information in order to make it more accessible to the general as opposed to the specialised reader.

Before proceeding further, it may be useful to say that a debate on the perspectives of climate scientists and sceptics allowed the stakeholders to ask critical questions in order to understand whether there is a critical climate change problem. The debate and discussions revealed that in the national context:

- There is consensus in the science about the existence of human-induced climate change. There is a link between emissions of GHGs, increased concentrations of these gases and a rise in temperature and other related impacts;
- There are uncertainties relating to the exact nature of the impacts;
- Sceptics have essentially three types of arguments, focusing on the uncertainties as if they mean unreliable science, focusing on the dubious nature of the combination of different types of science, and focusing on the high costs of taking action;
- The question-answer session revealed that the stakeholders believe that there is a serious problem, even if there may be some uncertainties; and that inevitably the cost of taking action will influence the way risks will be perceived.

This chapter takes the information from the stakeholders and scientists and tries to combine the cumulative knowledge. It first identified the key indicators climate change for the Netherlands (Section 8.3). It then uses the arguments of the stakeholders to look at the various ways of classifying the indicators and examines the advantages and disadvantages of each (Section 8.4). On the basis of the input from the stakeholders, it ranks the different indicators from a social perspective (Section 0). On the basis of the input from the scientists, it ranks the different indicators from a scientific perspective (Section 0). It then presents the indicators in a matrix of scientific and social criteria (Section 8.7). It combines the available information on threshold levels to provide data on what is acceptable and not acceptable for the Netherlands, and provides the reasons for each (Section 8.9). It then proceeds to make links to the concentration levels where that is possible (Section 0). It then provides recommendations for further research (Section 8.10), as well as policy recommendations (Section 8.12).

8.2 The chain of effects

Before delving into the details, it is important to remember that there is a clear chain of impacts in the climate change system and there are a number of positive and negative feedback effects. This can be summed up as follows:

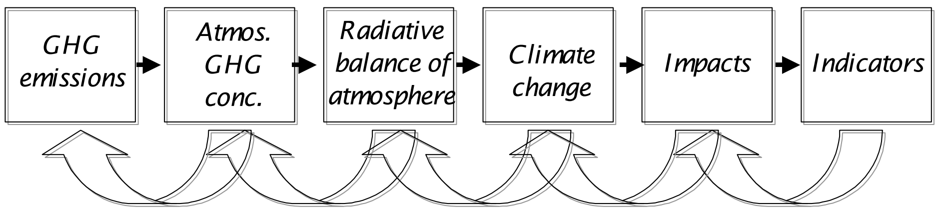

Figure 8.1 A simplistic representation of the cause-effect chain.

Emissions lead to increasing concentrations of GHGs in the atmosphere, which leads to a change in the radiation balance of the atmosphere. This leads to climate change, which has a number of impacts on society and ecosystems. This is a simplistic presentation of the chain of events. At the same time, from the indicators we can back-calculate the atmospheric GHG concentrations and the relevant emission level (see Chapter 5).

The following sections first evaluate key indicators of primary and secondary impacts, before making a correlation to temperature and concentrations.

8.3 Key indicators of climate change for the Netherlands

The stakeholders identified 19 indicators (see 7.3.3); we have split some of them into two indicators for the sake of clarity. As a result, we have reached a total of 24 indicators. These include 21 national level indicators and 3 international level indicators:

- Water quality: The problem of blue algae and botulism are seen as serious threats to water quality in the Netherlands and will affect the recreation and tourism industry by making water unsafe to swim in;
- Access to water: There is an expectation that the quality and quantity of water available to the households may be reduced by climate change, leading to restrictions in water use;
- Navigability of rivers: Climate change is expected to have an influence on water levels in the navigable rivers thus influencing transport in the rivers and the transport sector as a whole;
- Water temperature: The rise of the water temperature may both affect biodiversity and fish stocks and have socio-economic impacts, through the rationing of electricity related to cooling water availability;
- Agricultural productivity: Climate change is likely to influence agricultural productivity by influencing the quality and quantity of water available for crops;
- Absolute sea-level rise: Climate change is expected to lead to a rising sea-level; this continuous rise is expected to have a continuing impact on the Netherlands, long after concentration levels are stabilized;
- Rate of sea-level rise: An absolute sea-level rise implies that the sea-level is rising continuously. This is of immediate relevance to defining response actions of society;

- Spread of infectious disease: A rise in local temperatures may be accompanied by the spread of infectious diseases; the most serious identified threat was the Lyme disease spread by ticks. This could influence both the health sector and recreation possibilities;
- Death from heat waves: Another potential impact of the rise in summer temperatures is the rise in death rates especially of senior citizens. This may, however, be compensated by a decrease in death rates in the warmer winter months;
- Increased length of the pollinating season: It is anticipated that the length of the pollinating season will increase; if so this will have immediate impacts on chronic sicknesses such as allergic responses and asthma;
- The rate of disappearance of beaches: A rising sea-level can be dealt with by building dikes and dams (although at considerable cost), but not without severe consequences for beaches in the Netherlands. This will have impacts on the recreation and tourism sector;
- Reduced opportunities for ice-skating: With warming, there will be reduced opportunities for ice-skating and especially the 11 cities ice-skating event that the Dutch are so keen on;
- The effects on national income: There is an expectation that unilateral policy action in the Netherlands will have negative impacts on national income;
- The effect on other macro-economic factors, such as employment, vulnerable sectors, growth rates: Some sectors may in particular be vulnerable especially if energy prices rise as a result of energy related choices. As a counter effect climate change measures may have a positive spin-off;
- Floods: Extreme events will lead to, *inter alia*, floods in the Netherlands. Such flooding can have large consequences on infrastructure as well as human health and society;
- Storms: Other extreme events include storms. These are not expected to have quite as severe an impact as floods in the national context;
- Changes in the biodiversity: The biodiversity in the Netherlands is expected to change with the changing environment;
- Melting of glaciers: Glaciers are projected to continue their widespread retreat during the 21st century;
- Disintegration of the West-Antarctic ice sheet leading to a 1 metre extra sea-level rise per century for many centuries: An important international impact that is of direct relevance to the Netherlands is the possible disintegration of the West Antarctic ice sheet and its influence on the Netherlands;
- Changes to the Gulf Stream: Another impact is the possibility of a major change to the North Atlantic warm gulf stream leading to significant changes in the European climate;
- The disappearance of species: It is expected that ecosystems in Europe will shift pole ward by 300 kilometres for every degree warmer. This will lead to a gradual extinction of species in this part of the world. Particularly vulnerable regions in the Netherlands include the Wadden Sea.

Indicators purely of an international nature that were also seen as critical for the Netherlands included:

- Access to drinking water world-wide: Current access to drinking water world-wide is already a serious problem as recognized by the Millennium Development Goals; but it is expected that the climate change problem will exacerbate the situation much further;
- Access to food world-wide: As a result of changing temperatures and rainfall patterns, local access to food will also probably change negatively in most parts of the developing world;
- Impacts on North-South equity per se: The impacts of climate change are expected to be highly visible in the developing world. Coral reefs are already bleaching, glaciers are already melting and rainfall patterns are changing. This is expected to have a negative influence on the security in developing countries, and may have negative repercussions on the developed world.

An item that was not brought forward at the stakeholder discussion was the indicator of disappearance of nation states resulting from a rising sea-level; or other losses of inhabited land (see 7.2). This may have either been an oversight on the part of the stakeholders or on the part of the scientists.

8.4 Classification of indicators

The next question is how these indicators can best be classified and organized. The stakeholders had made a few suggestions (see 7.4.2). Classification of indicators facilitates their analysis. On the basis of the stakeholder and scientific discussions, the following systems of classification were seen as possible, each with its own advantages and disadvantages:

- In terms of geographical scale, the impacts may be primarily national (N); national and international (N&I); and primarily international (I);
- In terms of the nature of the effects, the impacts may be reversible (R); or irreversible (Ir);
- In terms of time scale, the impacts may be short-term (impacts already happening; ST); continuous (impacts that will continue to be felt now and in the future; C); or long-term (e.g. the disintegration of the West Antarctic Ice Sheet; LT);
- In terms of how people and, hence, politicians prioritise impacts: This was seen as important as it is a way to communicate climate change in a manner that is directly relevant to people. Although the group identified only four perspectives, in the earlier discussions, cultural and equity issues were also seen as important perspectives through which people look at critical social issues. These include health (H), ecosystem and environmental effects (Env.); security (S); economics (E); culture (Cul); equity (Eq.);
- In terms of sectors: Most policies are taken on a sectoral basis; and a sectoral division of problems makes it easier to access information and to devise policies to deal with problems. The following sectors appear to be relevant to the issues being discussed: water; food; health; economic; disasters (abrupt events, extreme events, irreversible events); ecosystems and environment, and foreign affairs.

The following table attempts at summarising the advantages and disadvantages of different types of classifications. The stakeholders could not come to agreement about the manner in which indicators should be classified. Table 8.1 lists the advantages and disadvantages of each classification system, in order to come to an assessment of which classification system can serve which purpose.

Table 8.1 The advantages and disadvantages of different classification systems.

Classifications	Advantages	Disadvantages
Geographical scale	One can show what will directly and indirectly affect Netherlands society; Climate change is a global problem, and there are reasons to justify a global approach.	It is often difficult to separate the purely national from the international dimensions of the problem, because of the close link between the two.
Time scale	Some impacts are already evident – it is not as if climate change is something that will happen in the future; but some impacts will continue long after we have stabilized emission levels because of the inertia in the system.	It complicates political discussions and often makes communication of the issues very complex.
Political perspective	It is useful to communicate the impacts in terms of what people prioritise at a personal or at the national level	It is (sometimes) difficult to explain the interrelatedness of perspectives. It may also be difficult to assign a certain perspective to someone.
Sectoral approach	Policies are often developed at sectoral levels, and it is useful to identify the sectors so that the impacts and responses can be related to the sectors.	The approach does not always match political priorities; and the sectors are also interrelated.
Nature of impacts	Classifying into reversible and irreversible will help to prioritise the impacts.	Too simplistic; some reversible impacts, may turn out to be irreversible and vice versa.

The above analysis of the advantages and disadvantages of the different approaches shows that each has something to add and is relevant. This has led us to conclude that none of these classification systems should be discarded in favour of another and instead we should focus on finding a way to combine the information. We have divided the indicators on a sectoral basis, since policies are often made on a sectoral basis. We have classified the indicators into 8 sectors (fresh water, seas, health, tourism, economic, environmental disasters, ecosystems and environment, and foreign affairs). We have then attempted to identify how each indicator can be classified in terms of the different classification systems (see Table 8.2).

Table 8.2 Classification of Indicators.

Sectoral classification	Indicator	Geog. Scale	Time Scale	Reversibility	Political perspective[32]
Water	Quality (nr. of weeks one cannot swim)	N	C	R	**H**, E
	Access to clean water	N	C	R	**H**, S
	Navigability of rivers (in weeks)	N	C	R	E
	Temperature	N	C	R&Ir	**Env**, E
	Productivity of land	N	C	R	E
SLR	Absolute (m)	N&I	LT[33]	Ir	S
	Rate (mm per year)	N&I	C	Ir	**S**, E, Env
Health	Spread of infectious disease	N&I	C	R	H
	Death from heat waves	N	C	Ir	H
	Allergies and other chronic sicknesses as a result of the increase in the length of the pollen season	N	C	R	H
Tourism	Rate at which the beach disappears	N	C	R	E
	No. of *Elfstedentochten*	N	C	R&Ir	**Cul**, E
Economic	Effects on income	N	C	R	E
	Effects on employment and sectors	N	C	R	E
Environmental disasters	Extreme events (floods)	N	C	R&Ir	S, H, **E**
	Extreme events (storms)	N	C	R&Ir	**S**, H, E
Ecosystems and environment	Change in biodiversity	N&I	C	Ir	**Env**, E, H
	Melting of glaciers	I	ST[34]	Ir	**S**, E
	Disintegration of the Antarctic	I, N	LT	Ir	**S**, H, E
	Impact on the Gulf Stream	N	LT	Ir	**S**, E,
	Disappearance of species	N&I	C	Ir	**Env**, E
Foreign Affairs	Access to drinking water	I	C	R	**Eq**, H
	Access to food	I	C	R	**Eq**, H
	Social instability through North-South impacts	I&N	C	R	Eq, **S**, E

[32] On the basis of recent arguments the project tem has chosen for highlighting one political perspective as dominant (shown in bold). The scores have been assigned on the basis of the perspective given in bold.

[33] Sea-level rise is a continuous process, but continues long after other effects are dealt with. We differentiate here between the rate of sea-level rise which is seen as a continuous process, and the absolute sea-level rise which is here marked as long-term, primarily because we want to emphasise the long-term effect.

[34] The argument for seeing the melting of glaciers as short-term, is because the glaciers are already melting, and once the damage is done they cannot continue to re-melt.

8.5 Successful indicators from a socio-political perspective

At the workshops, stakeholders argued that for a successful indicator, it must both appeal to society and be scientifically sound (see 7.3.4). In terms of appealing to society, an indicator must have a salient characteristic that is emotionally moving, and be understandable. We embark from the starting point that the selection of indicators show that these are all relevant for the Netherlands. However, some may be more important than others from the perspective of social actors. We have made some generic assumptions:

- For example, we assume that where there are clear national impacts, citizens will tend to give that most priority, where there are only international impacts, citizens will give it a lower priority;
- Where the problem is seen as continuous, people are likely to prioritise them over only short-term problems and these will likely be seen as more important than long-term problems;
- Irreversible problems are likely to be more of a priority than reversible problems;
- During the workshop, it was persuasively argued that different social actors have different perspectives and different issues will be seen as more or less important. Nevertheless, we argue below that involuntary health risks are likely to be the top priority of residents. If one has a larger exposure to a chronic sickness, this affects one's ability to function in ones private home (as parent, partner, or child), and in one's professional function. Economic risks have been selected as the second priority; because national income, employment effects and others are generally seen as vital in the society and often as a key reason for taking or not taking action. Cultural, equity, ecosystem and security perspectives are in general seen as third priority, since for most people, their own health tends to come first, followed by the effect of the economy on their lifestyles.

We have in any case made our prioritisation transparent; and if there are good reasons for changing these, these can always be undertaken (see Table 8.3). The fourth column shows how we value each of these aspects of the indicators.

The valuation (+,++,+++) in the fourth column of Table 8.3 is then applied to each indicator in Table 8.4. We then add up the total number of plusses and rank the indicators on the basis of assessing who has the highest number of plusses (see Table 8.5).

The purpose of undertaking this exercise is to see which indicators are in a position to be better communicated to the public in order to increase their awareness of the problem and their commitment to deal with the problem. In the column Political perspective, if there was more than one relevant perspective, we have given the value that the most important perspective had (e.g., if both health (+++) and economy (++) are affected, we have given the value +++). However, in some cases we have selected a dominant perspective and then the value assigned was that of the most important perspective.

From the total valuation, represented by the total amount of plusses an indicator has been given, a ranking can be made. Most important are the indicators with the most plusses; least important are the indicators with the smallest number of plusses (see Table 8.5).

Table 8.3 Prioritising indicators from a socio-political perspective.

	Top Priority	Second priority	Third priority	Valuation
Geographical				
National	x			+++
International and National	x			+++
International			x	+
Time-scale				
Continuous	x			+++
Short-term		x		++
Long-term			x	+
Reversibility				
Irreversible	x			+++
Reversible			x	+
Perspective				
Health	x			+++
Economic		x		++
Cultural			x	+
Equity			x	+
Ecosystem			x	+
Security			x	+

Table 8.4 Prioritising indicators on the basis of social criteria for national scale.

Sectoral classification	Indicator	Geog. scale	Time scale	Reversibility	Political perspective	Total 1+2+3+4	Rank
Water	Quality (the number of weeks one cannot swim)	+++	+++	+	+++	10	2
	Access to clean water	+++	+++	+	+++	10	2
	Navigability of rivers	+++	+++	+	++	9	3
	Temperature	+++	+++	++	+	9	3
	Productivity of land	+++	+++	+	++	9	3
SLR	Absolute	+++	+	+++	+	8	4
	Rate	+++	+++	+++	+	10	2
Health	Spread of infectious disease	+++	+++	+	+++	10	2
	Death from heat waves	+++	+++	+++	+++	12	1
	Allergies and other chronic sicknesses as a result of the increase in the length of the pollen season	+++	+++	+	+++	10	2
Tourism	Rate at which the beach disappears	+++	+++	+	++	9	3
	No. of *Elfstedentochten*	+++	+++	++	+	9	3
Economic	Effect on income	+++	+++	+	++	9	3
	Effect on work and sectors	+++	+++	+	++	9	3
Ecosys-	Extremes (floods)	+++	+++	++	++	10	2

tems and environment	Extremes (storms)	+++	+++	++	+	9	3
	Change in biodiversity	+++	+++	+++	+	10	2
	Melting of glaciers	+	++	+++	+	7	5
	Disintegration of Antarctic	+++	+	+++	+	8	4
	Impact on the Gulf Stream	+++	+	+++	+	8	4
	Disappearance of species	+++	+++	+++	+	10	2
Foreign affairs	Access to drinking water (globally)	+	+++	+	+	8	4
	Access to food	+	+++	+++	+	8	4
	Social instability through North-South impacts	+++	+++	+++	+	10	2

Note: +++ good; ++ medium; + poor.

Table 8.5 Ranking of the indicators by social criteria.

Score (number of plusses	12	10	9	8	7
# Indicators	1	9	8	6	1
Ranking	1	2	3	4	5

8.6 Scientific prioritisation of indicators

A successful indicator also needs to meet scientific criteria. The key scientific criteria which were identified by the stakeholders, including scientists are representativeness, attributability, measurability and computability. These criteria were evaluated as good (+++), medium (++) and poor (+) on the basis of the best available scientific judgement. When this is used, the sum of the valuation can be used to make a ranking. This ranking can be found in the last column of Table 8.6.

8.7 Towards classifying the indicators

Having first undertaken a ranking of the indicators on the basis of scientific and social criteria, we now attempt to further integrate this information in a matrix.

Table 8.8 integrates the scientific and social ranking, but can also be read diagonally. The top left corner indicates indicators that are both scientifically sound and socially appealing. The bottom right indicators are less directly attributable to climate change and perhaps less appealing as social indicators but are nevertheless seen as important by social actors. Reading from top left to bottom right, one can classify the indicators into 7 categories of priorities.

8.8 Incorporating threshold levels

Table 8.6 below incorporates threshold levels of risk for the 7 categories of indicators on the basis of the stakeholder discussions. It uses their arguments to extrapolate threshold levels for other indicators (see 0).

Table 8.6 Prioritising indicators on the basis of scientific criteria for national scale.

Sectoral classification	Indicator	Representative	Measurability	Computability	Score	Rank
Water	Quality (the number of weeks one cannot swim)	++	+++	++	7	2
	Access to clean water	+++	+++	++	8	1
	Navigability of rivers (in weeks)	+++	+++	++	8	1
	Temperature	+++	+++	++	8	1
	Productivity of land	++	+++	++	7	2
SLR	Absolute (m)	+++	+++	++	8	1
	Rate (mm per year)	+++	+++	++	8	1
Health	Spread of infectious disease	++	+++	++	7	2
	Death from heat waves	+++	+++	+	7	2
	Allergies and other chronic sicknesses as a result of the increase of the length of the pollen season	+++	+++	++	8	1
Tourism	Rate at which the beach disappears	++	++	+	5	4
	No. of *Elfstedentochten*	++	+++	++	7	2
Economic	Effect on income	+++	++	+	6	3
	Effect on work and sectors	++	+++	++	7	2
Environmental disasters	Extreme events (floods)	+++	+++	+	7	2
	Extreme events(storms)	+	++	+	4	5
Ecosystems and environment	Change in biodiversity	++	++	+	5	4
	Melting of glaciers	+++	+++	++	8	1
	Disintegration of the Antarctic	++	++	+	5	4
	Impact on the Gulf Stream	+++	++	+	6	3
	Disappearance of species	+++	++	+	6	3
Foreign affairs	Access to drinking water	++	++	+	5	4
	Access to food	++	+	+	4	5
	Social instability through North-South impacts	++	+	+	4	5

Note: +++ good; ++ medium; + poor.

Table 8.7 Ranking of the indicators by scientific criteria.

Score (number of plusses)	8	7	6	5	4
# Indicators	8	6	6	2	2
Ranking	1	2	3	4	5

Table 8.8 Prioritising on the basis of the ranking of scientific and social criteria.

	Ranking of scientific criteria				
Ranking of social criteria	**1**	**2**	**3**	**4**	**5**
1		Death from heat waves (A)			
2	Access to clean drinking water; Rate of sea-level rise Allergies (length pollen season) (A)	Water quality (number of weeks one cannot swim) Spread of infectious disease; Floods (B)	Disappearance of species (C)	Change in biodiversity (D)	Social instability (North vs South) (E)
3	Navigability of rivers; Water temperature. (B)	Productivity of land; Effect on work and sectors; No. of ice-skating events (*Elfstedentochten)* (C)	Effect on income (D)	Rate at which the beach disappears (E)	Storms (F)
4	Absolute sea-level rise (C)		Impact on Gulf Stream (E)	Disintegration of Antarctic; Global access to drinking water (F)	Access to food (G)
5	Melting of glaciers (D)				

8.9 Incorporating threshold levels

Table 8.9 below incorporates threshold levels of risk for the 7 categories of indicators on the basis of the stakeholder discussions. It uses their arguments to extrapolate threshold levels for other indicators (see 0)

Table 8.9 Potential threshold levels for each indicator.

Priority	Indicator	Acceptable risk	Not acceptable
A	Access to clean drinking water	That there is a temporary ban on washing cars; or watering gardens	That children cannot bathe; or you cannot drink water from the tap;
	Death from heat waves	Mortality remains stable	An increase in mortality
	Allergies and other chronic sicknesses due to longer pollen season		Structural increase in chronic sicknesses

	Rate of sea-level rise	20 cm per century	> 50 cm per century; > 3 mm per year, because of the devastating effects on the Wadden sea
B	Water quality (number of weeks one cannot swim)	An increase of 50% from current levels;	An increase of 200%; Structural effect annually
	Navigability of rivers	Incidentally less load	Over four weeks less load Over two weeks less load
	Water temperature	An incidental rise leading to fish kills	Structural rise leading to loss of biodiversity; Code red: Electricity is rationed, because of the impact on electricity production
	Spread of infectious disease	An increase in the chance of falling ill	If adaptation is no longer possible, or if the costs for adaptation are out of proportion
	Floods	Incidental increases	Structural increases affecting property values
C	Productivity of land	Incidental losses	Structural losses
	Absolute seal level rise	Marginal increases	> 0.5 m too costly
	Effect on work and sectors	Marginal changes	Income inequality increases
	Disappearance of species	Incidental losses	Where the legal norms are exceeded and structural losses
	The number of major skating events (Elfsteden tochten)	Less than current levels	Less than once every ten years
D	Effect on income	Incidental loss of income	No growth as result of impacts for one year; If Netherlands competitiveness is affected
	Change in biodiversity	Incidental changes	Loss of key species and ecosystem functions
	Melting of glaciers	Incidental changes	Structural large-scale
E	Impact on the Gulf Stream	Negligible chance	Increase of probability
	Rate at which the beach disappears	When the beach can be easily replenished	When replenishment is too expensive affecting tourism
	Instability through North-South impacts	At current levels	Should not increase structurally
F	Disintegration of the Antarctic	Negligible chance	Increase of probability
	Global access to drinking water	Should meet Millennium Development Goals	Should not become worse than today
	Storms	Current levels	Should not increase structurally

G	Access to food	Current problems	When this leads to international instability and significant increase in financial inequality

8.10 Making links to temperature levels

Local climate thresholds for impacts need to be converted to global indicators, because of the larger-scale context of global warming and climate policy. For example, temperature change averaged over the Netherlands is projected to increase with a factor of about 1.1 as compared to the global mean. When local impact thresholds have been translated to global indicators, the latter need to be related to GHG concentration targets, before the implications for near- to mid-term emission pathways can be determined. The dominant uncertainty in this step is in the value of the climate sensitivity. This is the equilibrium global-mean surface-air temperature increase resulting from a doubling of the CO_2 (equivalent) concentrations in the atmosphere compared to pre-industrial levels. By use of recent probability estimates of this parameter, risk assessment becomes possible, which is a useful method for evaluating policy options in the context of major uncertainties (see Chapter 5). In this approach, the question is not which concentration level results in limiting global-mean temperature to a maximum defined by the impact thresholds. Rather, questions like this need to be rephrased to which concentration levels result in a probability of at least x% that global-mean temperature will be limited to a maximum defined by the impact thresholds. Obviously, setting threshold levels and assigning a pursued probability level (x%) is the task of policy makers and stakeholders.

The following section attempts to make a link between the impacts to the temperature levels. We have tried to classify the different impacts of climate change that are likely to occur at different levels of temperature increases. This was a complex effort and tries to incorporate both the science and the perceptions of climate change. We have used a colour code to show the impacts that appear to be unacceptable.

Figure 8.1 is a first attempt to present clearly a set of ambiguous impacts, and it thus faces the limitation that it might be presenting the information incorrectly. Nevertheless, in the interests of presenting science in an understandable manner to the public we have developed this figure and are willing to modify it as and when more information becomes available.

The figure below shows that beyond 2 ºC, there are too many risks for the Netherlands. Chapter 5 argues that for stabilization at 550 ppmv CO_2-eq. the probability of limiting temperature increase to 2 ºC is about 33-50%. For stabilization at 650 ppmv this decreases to less than 10-33% (see 5.5). Hence, this chapter recommends that from a Netherlands' perspective global concentrations need to be well below 550 ppmv CO_2-eq. This is in line with the current thinking in some other EU countries and the European Council's decision (see 7.5).

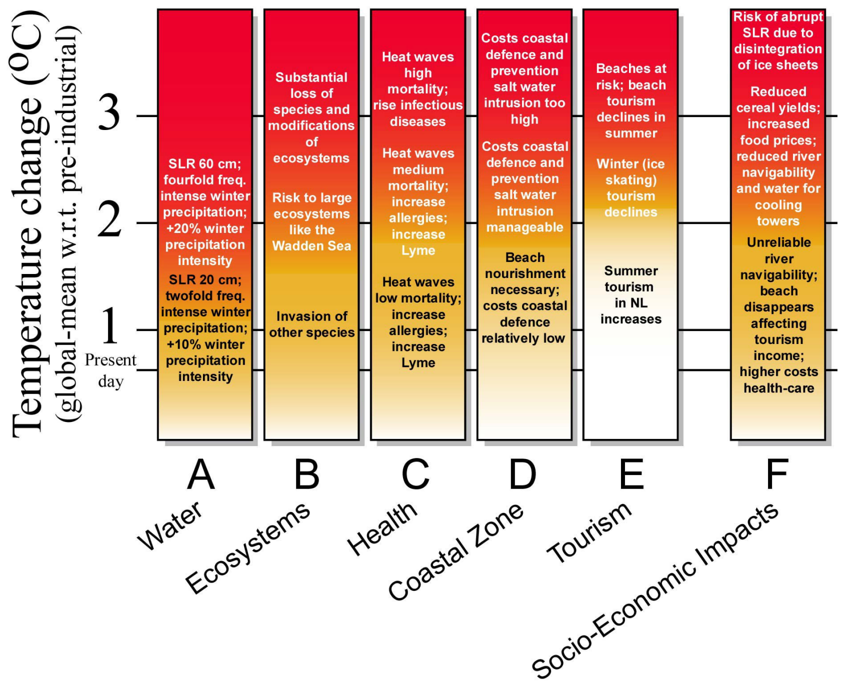

Figure 8.1 Perceived reasons for concern in the Netherlands.

Note: Perceived reasons for concern in the Netherlands. N.B. impacts are for 2100.

8.11 Recommendations for further research

What became amply clear in the course of the project was that although there is considerable general information on climate change science, specific information on the impacts of climate change on Netherlands society and their possible costs was relatively much less available. The project team identified the following gaps in the available scientific literature:

- Further scientific research to increase knowledge about regional climate change and the associated impacts;
- Considerable uncertainty exists in the estimates of the probability distribution of the climate sensitivity. An evaluation of the differences between currently applied methodologies and an assessment of the associated reliability is recommended;
- In the past decade, most research efforts have been put into estimating mitigation costs associated with stabilization of GHG concentrations. New research is required to evaluate peaking and overshoot profiles that might provide more cost-effective options to achieve the same long-term climate targets;
- Probability estimates, concentration estimates, and assessments of emission pathways and associated emission reduction costs are currently performed as single issues by different (modeling) tools and research groups. An integrated (modeling) framework capturing all these issues is required in the light of inconsistencies like different baseline scenarios, reduction options, greenhouse-gas mixtures and climate system characteristics;

- Further scientific research and discussions with national stakeholders on further elaboration of and the robustness of the threshold levels for the indicators is needed;
- In addition, in order to gain momentum for the political action needed, global science-policy dialogues on long-term climate targets need to be supported. This is necessary since the negotiations are continuously focused on short-term goals and the long-term perspective is often lost.

8.12 Recommendations for policy

This document comes with the following policy recommendations:

First, the research indicates that the state of the current science and the initial discussions with stakeholders show that there are good reasons to support a 2 °C limit to the increase in the temperature by the end of this century; although there are some doubts about the potential to make the link with GHG concentration levels, the project team supports the idea that a 2 °C limit corresponds to a 500-550 ppmv CO_2 equivalent concentration levels. This conclusion was reached based on some arguments. The scientific arguments were:

- Beyond 2 °C global warming in relation to pre-industrial levels, there is consensus that the climatic and ecological system could become unstable and irreversible impacts may become inevitable;
- It should be noted that 2 °C, also implies huge losses to some low-lying countries and some ecosystems;
- The 2 °C target may already have been exceeded if the sensitivity of the climate system to emissions is higher than currently expected; in other words if the current emissions of aerosols is masking the enhanced greenhouse effect to some extent; (however, the IPCC has not yet made any firm assessment of the situation as yet);
- Taking all the above into account, it was agreed that on the basis of the current science, a 2 °C target in combination with current expectations that this coincides with a 500-550 ppmv CO_2-eq. concentration level seems to be the most reasonable long-term target for the Netherlands.

From a political perspective, there were some discussions:

- Modifying a 2 °C target to a 3 °C target would reduce the urgency for action and increase the risk of instability in the system; this risk was not seen as politically acceptable. Besides, beyond 3 °C the biosphere could become a source rather than a sink of GHGs which could lead to fast, additional increases in atmospheric greenhouse gas concentrations and further, strong temperature changes;
- Reducing a 2 °C target to something lower does not seem at all feasible, especially because of the short-term social and economic implications[35];
- Should the science indicate that the climate system is more sensitive to emissions this would only imply that the urgency to take measures will increase drastically, and this is an additional argument for not relaxing the 2 °C target;

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[35] Even a 2°C target appears less feasible in the Dutch context, according to a selection of Dutch stakeholders (see Hisschemöller & van de Kerkhof, 2004, on the feasibility of a –30% target in 2020).

- The perspectives of other large EU member states on the issue strengthens the political argument since the Netherlands is then not alone in this perspective.

Second, the current medium-term target under discussion, of reducing emissions by 30 % would appear to be consistent with the long-term goal of a 2 °C target. It would also appear to be the next logical step from the Kyoto target. However, this target was never specifically studied under this project. The research concludes that from the perspective of scientific consistency with the long-term goal and from the political perspective that many neighbouring countries are thinking along parallel lines, this short-term goal would appear a reasonable aspirational target, even though there are some reservations about its actual feasibility in the short-term.

References

Hisschemöller, M. & Van de Kerkhof, M. (2004). *Europa, Nederland: How verder na Kyoto? Aanbevelingen van stakeholders voor het Nederlands EU Voorzitterschap*, Platform Communication on Climate Change, RIVM.

Appendix I. List of Fact Sheets prepared for the Stakeholders

1. Climate change;
2. The Third Assessment IPCC Report;
3. Climate change targets and GHG emissions;
4. Biodiversity and ecosystems;
5. Fresh water;
6. Coastal zone;
7. Health;
8. Recreation and tourism;
9. Macro-economic effects.

For details in the Dutch language, see the IVM website: http://www.vu.nl/ivm >Research projects>Re-evaluation climate targets.

Appendix II. Interview questions

Artikel 2 van het Raamverdrag van de Verenigde Naties inzake klimaatverandering (UNFCCC) luidt:

Het uiteindelijke doel van dit Verdrag (…) is het bewerkstelligen, in overeenstemming met de desbetreffende bepalingen van het Verdrag, van een stabilisering van de concentraties van broeikasgassen in de atmosfeer op een niveau waarop gevaarlijke antropogene verstoring van het klimaatsysteem wordt voorkomen. Dit niveau dient te worden bereikt binnen een tijdsbestek dat toereikend is om ecosystemen in staat te stellen zich op natuurlijke wijze aan te passen aan klimaatverandering, te verzekeren dat de voedselproduktie niet in gevaar komt en de economische ontwikkeling op duurzame wijze te doen voortgaan.

1. Wat is volgens u het grootste gevaar voor de Nederlandse samenleving ten gevolge van klimaatverandering?
2. Denkt u dat de drie genoemde voorwaarden in Artikel 2 ("ecosystemen in staat stellen zich op natuurlijke wijze aan te passen", "verzekeren dat de voedselproductie niet in gevaar komt", "de economische ontwikkeling op duurzame wijze te doen voortgaan") voldoende zijn om een niveau te bepalen waarop de concentratie broeikasgassen "gevaarlijk" wordt? Bevat het artikel onvolkomenheden en/of ontbreken er andere condities in het artikel?
3. Zijn alle drie de voorwaarden even belangrijk? Hoe zou u ze eventueel rangschikken (bijv. 1. ecosystemen, 2. voedselproductie 3. duurzame economische ontwikkeling)?
4. Wanneer wordt volgens u niet meer aan de voorwaarden van artikel 2 voldaan? (M.a.w. moeten alle ecosystemen in staat zijn zich op natuurlijke wijze aan te passen of slechts een deel? Moet de voedselproductie overal verzekerd zijn of slechts op bepaalde plekken in de wereld? Moeten alle vormen van economische activiteit zich duurzaam ontwikkelen of is het niet ernstig wanneer dit op een andere manier gebeurd?)
5. Wat is volgens u een onacceptabel klimaatrisico (in de zin van het vermijden van maatschappelijke gevolgen)?
6. Welke gevolgen/uitkomsten van het internationale klimaatbeleid zou u niet acceptabel vinden? Aan welke voorwaarden moet het klimaatbeleid volgens u voldoen?
7. Het stabiliseren van de concentraties van broeikasgassen op een bepaald niveau door het verminderen van emissies brengt kosten met zich mee. Tevens brengt het aanpassen (adaptatie) aan de effecten van klimaatverandering kosten met zich mee. Hoe moeten deze kosten wereldwijd verdeeld worden?
8. Wat zullen volgens u de meest controversiële aspecten zijn bij het bediscussiëren van artikel 2?

9. Welke overige beleidskwesties zouden volgens u ook betrokken moeten worden in een discussie over en/of een interpretatie van artikel 2?
   - Internationale handel (WTO);
   - Nationale veiligheid;
   - Internationale veiligheid;
   - Internationale machtsrelaties;
   - Religieuze of ideologische principes;
   - Culturele verschillen;
   - Overige, te weten: (graag specificeren).
10. Wat is naar uw mening het belangrijkste dat besproken moet worden tijdens de workshop?
11. Weet u andere personen die geschikt zouden zijn om te benaderen voor de workshop?

Appendix III. List of Workshop Participants

Workshop 1

Chair

	Eimert van Middelkoop	First Chamber, ChristenUnie

Participants

1.	W.G. Albrecht	Platform Biologica	NGO
2.	Henriëtte Bersee	Min. VROM	Government
3.	Marc Beurskens	Institute for Plasma Physics RIJNHUIZEN	Science
4.	Hendrik Jan Bosch	Milieudienst Rijnmond	Government
5.	Richard Braakenburg v. Backum	Min. V&W	Government
6.	Jos Bruggink	ECN Policy Studies	Science
7.	Bas Clabbers	Min. LNV	Government
8.	Resianne Dekker	Port of Rotterdam	Industry
9.	Hugo Denier van der Gon	TNO-MEP	Science
10.	Bopp van Dessel	Stichting ProSea	NGO
11.	Floris Groenendijk	Stichting de Noordzee	NGO
12.	René Jacobs	Shell Global Solutions International B.V.	Industry
13.	Hans Labohm	Clingendael	Science
14.	Frank van der Meulen	RIKZ	Science
15.	Bertus Postmus	Gasunie	Industry
16.	Sible Schöne	Wereld Natuur Fonds	NGO
17.	L. Sjerps	Vereniging Klimaatverbond	NGO
18.	Willem Takken	Wageningen Universiteit	Science
19.	Dirk JanTreffers	Universiteit Utrecht	Science
20.	Gert Uittenbogaard	DHV	Industry
21.	Wendela de Vries	Vereniging Milieudefensie	NGO

Project team

1.	Bas Amelung	International Centre for Integrative Studies
2.	Harro van Asselt	IVM, VU
3.	Marcel Berk	RIVM
4.	Hendrik Buiteveld	RIZA
5.	Edwin Dalenoord	IVM, VU
6.	Joyeeta Gupta	IVM, VU
7.	Lars Hein	Wageningen Universiteit
8.	Onno Kuik	IVM, VU
9.	Rik Leemans	Wageningen Universiteit
10.	Albert Oost	RIKZ
11.	Michiel Schaeffer	RIVM
12.	Koos Verbeek	KNMI
13.	Mick van der Wegen	Unesco-IHE

Workshop 2 Participants

Chair

Eimert van Middelkoop	First Chamber	Government

Participants

Wolfgang Albrecht	Platform Biologica	NGO
Dicky Bloemendaal	Verbond van Verzekeraars	Industry
Richard. Braakenburg van Backum	Ministerie van Verkeer en Waterstaat	Government
Resianne Dekker	Port of Rotterdam	Industry
Armande van Duin	Ministerie van EZ	Government
Rene Jacobs	Shell	Industry
Anthon Luijendijk	Kerk en Milieu	NGO
Bertus Postmus	Nederlandse Gasunie	Industry
Sible Schöne	Wereld Natuur Fonds	NGO

Project team

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Joyeeta Gupta	IVM
Bert-Jan Heij	NRP
Rik Leemans	Wageningen Universiteit
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